

XVIIth International Congress of Medicine

LONDON: 1913



SUB-SECTION VII (b)

Anæsthesia, General and Local

PART I

LONDON

HENRY FROWDE

HODDER & STOUGHTON

OXFORD UNIVERSITY PRESS

WARWICK SQUARE, E.C.

1913

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SUB-SECTION VII (b)

ANÆSTHESIA, GENERAL AND LOCAL

DISCUSSION No. 1

RECENT METHODS FOR PRODUCING ANALGESIA

REFERAT VON PROFESSOR DR. HEINRICH BRAUN IN ZWICKAU

UEBER DIE NEUEREN FORTSCHRITTE DER LOKAL- ANAESTHESIE IN DER CHIRURGIE

DIE Anwendung der lokalen Anästhesie beschränkte sich bis vor etwa zehn Jahren in der Hauptsache auf die sogenannte kleine, ambulatorische Chirurgie. Nur von einzelnen Spezialisten wurden manche typische Operationen der grossen Chirurgie mehr oder weniger regelmässig in Lokalanästhesie ausgeführt. Allgemeinen Eingang hatte letztere aber trotz der Bemühungen einiger hervorragender Männer in den chirurgischen Kliniken und Krankenanstalten ebensowenig gefunden, wie bei den praktischen Aerzten. Aus einem Stiefkind ist die Lokalanästhesie im Laufe des letzten Jahrzehnts zu der im allgemeinen wichtigsten Anästhesiemethode geworden. Denn in nicht wenigen chirurgischen Krankenanstalten—wenigstens Deutschlands—werden jetzt bereits regelmässig mehr als 50 Prozent aller Operationen an *stationären* Kranken in Lokalanästhesie ausgeführt, in den *Ambulatorien* verschiebt sich das Prozentverhältnis noch mehr zu Gunsten der Lokalanästhesie, und in einigen Sondergebieten der Chirurgie, wie der Stomatologie, werden Narkosen nur noch ausnahmsweise gebraucht.

Es wird meine Aufgabe sein, Ihnen die wesentlichen Punkte dieser ausserordentlichen Entwicklung der Lokalanästhesie heute vor Augen zu führen.

Ich verstehe unter Lokalanästhesie einen Zustand örtlicher Gefühls- lähmung, welcher entsteht, wenn die peripheren Endorgane der sensiblen Nerven ausser Funktion gesetzt sind (*terminale Anästhesie*) oder durch Leitungsunterbrechung sensibler Bahnen den Zusammenhang mit dem Zentrum verloren haben (*Leitungsanästhesie*). Theoretisch gehören demnach die *intraspinalen Injektionsmethoden* zur Lokalanästhesie. Denn sie sind eine besondere Form von Leitungsanästhesie. Da sie aber praktisch in einem grundsätzlichen Gegensatz zur Lokalanästhesie sich befinden, trennt man sie mit Recht von dieser. Den Ausdruck 'regionäre Anästhesie' werde ich nicht brauchen, weil ihm in verschiedenen Ländern eine verschiedene Bedeutung beigelegt wird.

Dasjenige, was den Aufschwung der Lokalanästhesie ermöglicht hat, ist der Ersatz des Kokains durch weniger toxische Mittel und die Einführung des Suprarenins (Adrenalins) in die Chirurgie durch den Referenten im Jahre 1903. An Stelle des Kokains ist überall in der Chirurgie das ebenfalls vom Referenten auf Grund der Ergebnisse experimenteller Untersuchungen im Jahre 1905 eingeführte *Novokain* (Novokainchlorid) getreten. Man kann von diesem Mittel, unter der Voraussetzung, dass relativ verdünnte ($\frac{1}{2}$ –1 prozentige) Lösungen angewendet werden und ihnen Suprarenin zugesetzt wird, eine Dosis bis zu mindestens $1\frac{1}{2}$ Gramm brauchen, das sind also 300 ccm $\frac{1}{2}$ prozentige oder 150 ccm 1 prozentige Lösung. Mit konzentrierten Lösungen ist dagegen diese Dosierung wesentlich einzuschränken. Letztere werden aber auch nur zur Unterbrechung einzelner Nervenstämme und in der Zahnheilkunde gebraucht.

Durch Zusatz von sehr wenig *Suprarenin* gewinnen diese Lösungen, von denen so grosse Mengen injiziert werden dürfen, ein Anästhesievermögen *von bisher unbekannter Intensität und Dauer*. Zugleich wird die Blutung aus dem Operationsfeld wesentlich eingeschränkt, was für gewisse Operationen von grosser Bedeutung ist. Der Suprareninzusatz beträgt etwa 1 mg auf 200 ccm $\frac{1}{2}$ prozentiger oder 100 ccm 1 prozentiger oder 50 ccm 2 prozentiger oder 25 ccm 4 prozentiger Novokainlösung. Die *Dosierung des Suprarenins* ist für die Lokalanästhesie ohne Belang. Denn die hier gebrauchten Mengen können niemals Schaden verursachen. Dagegen sollte die eben genannte *Konzentration des Suprarenins* in den Lösungen, wenigstens bei Gewebsinjektionen, in der Regel nicht überschritten werden. Denn von ihr ist die Intensität der örtlichen Suprareninanämie abhängig. Eine zu starke Suprareninwirkung aber kann die Blutzirkulation im Operationsfeld vollständig unterbrechen, die Unterbindung der Gefässe erschweren und Gangrän verursachen in Geweben, welche bereits in ihrer Ernährung gestört sind (arteriosklerotische Extremitäten, Weichteillappen), und sich deshalb der in sie injizierten Mittel schwer wieder entledigen können.

Nach Gros¹ wirkt *Novokainbikarbonat* stärker anästhesierend, als das sonst gebräuchliche Novokainchlorid. Ferner haben Hoffmann und Kochmann² die Beobachtung gemacht, deren Richtigkeit ich bestätigen kann, dass die Novokainwirkung verstärkt wird, wenn man seinen Lösungen *Kaliumsulfat* (4 Prozent) zufügt. Aber das Suprarenin kann dadurch nicht ersetzt werden. Vielmehr sind in suprareninhaltigen Novokainlösungen die Unterschiede zu Gunsten des Novokainbikarbonats oder zu Gunsten der kaliumhaltigen Lösungen sehr unbedeutend. Weitgehende praktische Folgerungen werden sich deshalb an diese Beobachtungen voraussichtlich nicht knüpfen.

Die Novokain-Suprareninlösungen werden unmittelbar vor dem Gebrauch hergestellt, entweder aus Novokaintabletten, welche den

¹ *Archiv f. exp. Pathologie und Pharmakologie*, Bd. lxii, lxiii und lxvii, 1910 und 1912.

² *Deutsche med. Wochenschrift*, 1912, No. 48.

erforderlichen Suprareninzusatz enthalten. Solche werden in Deutschland von den Höchster Farbwerken fabriziert. Als Lösungsmittel dient physiologische Kochsalzlösung. Setzt man dieser auf den Liter etwa drei Tropfen verdünnte Salzsäure zu, so vertragen die Tablettenlösungen ohne Schaden eine Sterilisation durch Auskochen. Oder man hält eine 4 prozentige sterilisierte Novokainlösung vorrätig, verdünnt sie vor dem Gebrauch in der gewünschten Weise durch physiologische Kochsalzlösung und setzt von einer sterilisierten Suprareninlösung 1 : 1000 die erforderliche Menge in Tropfenform zu.

Für die *Oberflächenanästhesierung* der Schleimhäute ist das Novokain weniger geeignet; es vermag augenscheinlich die Schleimhaut weniger leicht zu durchdringen, als andere Mittel. Daher braucht man Kokain noch in der Ophthalmologie, Laryngologie und Rhinologie. Für die Chirurgen aber ist es obsolet geworden, und wir wollen diesem Mittel, welches so vielen Menschen das Leben gekostet hat, keine Träne nachweinen. Von den Ersatzmitteln eignet sich für die Schleimhautanästhesierung nach unseren Erfahrungen das *Alypin* am besten. Wir verwenden dasselbe in 2–5 prozentiger Lösung mit Suprareninzusatz bei der Oesophagoskopie, Bronchoskopie, in der Urethra und Blase u.s.w. Die Lösungen werden, wie die Novokainlösungen, *unmittelbar vor dem Gebrauch* aus Tabletten bereitet.

Das Novokain kann den peripheren Nervelementen auf zwei Wegen zugeführt werden: *durch Injektion in ein Blutgefäß*, wonach Anästhesie im Stromgebiet desselben eintritt, oder durch *Gewebsinjektion*.

I. DIE INTRAVASKULÄREN METHODEN

Die im Jahre 1909 von Bier erfundene Venenanästhesie, deren oft beschriebene Technik ich als bekannt voraussetzen darf, besteht bekanntlich darin, dass in einem durch Auswickeln blutleer gemachten und abgeschnürten Teil einer Extremität eine der oberflächlichen Venen freigelegt wird. In die Vene werden mittelst einer eingebundenen Kanüle je nach der Dicke und Grösse des Gliedabschnitts 40–100 ccm $\frac{1}{2}$ prozentige Novokainlösung injiziert. In diesem Gliedabschnitt tritt nach einigen Minuten Anästhesie ein. Biers Venenanästhesie ist für alle aseptischen Operationen an den Extremitäten, etwa von der Mitte des Oberarms und Oberschenkels abwärts — ausgenommen sind die Amputationen bei Arteriosklerose — ein gefahrloses und zuverlässiges Anästhesieverfahren. Seine Nachteile bestehen in der Belästigung des Kranken durch die abschnürende Binde bei länger dauernden Operationen und in der schnellen Rückkehr der Sensibilität nach Lösung der abschnürenden Binde. Der erstgenannte Nachteil kann durch Anwendung schonender Kompressorien wesentlich gemildert werden, der zweite hat zur Folge, dass die Operation vor Lösung der Kompression ganz fertig sein muss. Bei Amputationen wird hierdurch die exakte Blutstillung erschwert. Die zur Venenanästhesie angewendete Novokainlösung soll *keinen*

Suprareninzusatz haben. Letzterer bringt die Gefäße zur Kontraktion und hindert die gleichmässige Verteilung der injizierten Flüssigkeit.

Goyanes, v. Oppel und Ransohoff haben in ähnlicher Weise eine *arterielle Anästhesie* erzielt. Als Injektionsstelle diente die A. radialis, dorsalis pedis, femoralis und brachialis. Das Glied wird nach Goyanes zuvor, wenn es möglich ist, blutleer gemacht und abgeschnürt. Unterhalb der Kompressionsbinde wird das Anästhetikum (50–100 ccm $\frac{1}{2}$ prozentige Novokainlösung) mit feiner Nadel in die in Lokalanästhesie freigelegte Arterie injiziert. Kleinere Mengen von Novokain genügten nach v. Oppel nicht. Ransohoff injizierte 4–8 ccm $\frac{1}{2}$ prozentige Kokainlösung. Nach Hotz braucht man für die A. brachialis 20–25 ccm, für die A. femoralis 40 ccm $\frac{1}{2}$ prozentige Novokainlösung mit Suprareninzusatz. Die Abschnürung oberhalb der Injektionsstelle ist unerlässlich. 1–2 Minuten nach der Injektion trat vollkommene Anästhesie im Stromgebiet der Arterie ein. Nach Lösung der abschnürenden Binde kehrte die Sensibilität in der Regel sehr schnell zurück.

Den Uebelstand, dass die Extremität oberhalb des anästhetischen Gebiets abgeschnürt werden muss, und dass die Sensibilität nach Entfernung der Binde schnell wiederkehrt, teilt also die arterielle Anästhesie mit der Venenanästhesie. Dieser gegenüber hat sie den Nachteil, dass das Aufsuchen der Arterie wesentlich komplizierter ist, als das Freilegen einer Hautvene. Der von v. Oppel und Girgolaw betonte angebliche Vorteil, dass die Anästhetica bei intraarterieller Injektion weniger toxisch seien, als bei intravenöser, hat keine praktische Bedeutung, weil die intravenöse Injektion von Novokain *bei gleichzeitiger Unterbrechung des Blutstroms* ganz gefahrlos ist. Es ist deshalb nicht wahrscheinlich, dass die arterielle Anästhesie konkurrenzfähig gegenüber der einfacheren Venenanästhesie sein wird.

Die ersten Forscher, welche die nach intraarterieller Injektion von Kokain entstehenden Lähmungen im Stromgebiet der betreffenden Arterie bei Tieren beobachtet und beschrieben haben, waren Alms¹ und Maurel². Letzterer hatte ebenfalls angegeben, dass Kokain weniger toxisch sei bei intraarterieller Injektion, als bei Injektion in eine Vene. Nach meinen eigenen im Jahre 1900 vorgenommenen Tierversuchen³ ist Kokain bei Injektion in eine Arterie *mit freier Zirkulation* ebenso toxisch, wie bei Injektion in eine Vene mit freier Zirkulation.

2. DIE GEWEBSINJEKTIONEN

Die Gewebsinjektion besteht entweder in einer systematischen *Infiltration* bestimmter Gewebsschichten oder in *Injektionen* an einzelne grössere Nervenstämme.

Die *Infiltration*, wozu in der Regel $\frac{1}{2}$ prozentige Novokain-Suprarenin-Lösung (NS.-Lösung) dient, führen wir, abweichend von Reclus und Schleich, von möglichst wenigen Einstichpunkten mit langen Hohladeln

¹ Archiv f. Anatomie u. Physiologie, 1886.

² La Cocaïne, Paris, 1895.

³ Mitgeteilt in meinem Handbuch *Die Lokalanästhesie*, I. Aufl., 1905.

aus. Da also jeder Einstichpunkt wiederholt zum Einführen der Hohl-
nadel bestimmt ist, empfiehlt es sich, diese Einstichpunkte zuvor durch
je eine Quaddel zu markieren und unempfindlich zu machen. Die tiefsten
Gewebschichten werden stets zuerst, das Unterhautzellgewebe wird
zuletzt infiltriert.

Im Bereich der Gewebsinfiltration entsteht terminale *Infiltrations-
anästhesie*. Das injizierte Anästhetikum unterbricht aber auch die
Leitung derjenigen Nervenstämmen, welche durch die infiltrierte Gewebs-
schicht laufen. Daher verursacht jede Gewebsinfiltration zugleich auch
Leitungsanästhesie.

Wir benutzen bei Operationen selten das unmittelbare Ergebnis der
Infiltration, die Infiltrationsanästhesie, viel häufiger dagegen die durch
die Infiltration entstehende Leitungsanästhesie.

Die Haut braucht niemals infiltriert zu werden. Denn sie wird schon
unempfindlich, wenn das Unterhautzellgewebe infiltriert ist, von dem
aus die darüberliegende Haut innerviert wird. Das Periost empfängt
seine Innervation nicht aus dem Knochen, sondern von aussen. Man
muss daher nicht subperiostale Injektionen machen, sondern das Anä-
sthetikum von aussen an das Periost injizieren.

Die beabsichtigte Schnittlinie wird nur selten infiltriert. In der
Regel vielmehr wird eine rings das ganze Operationsfeld umgebende
Gewebschicht von sorgsam ausgewählten Einstichpunkten aus infiltriert.
Dadurch wird die gesamte Innervation des Operationsfeldes unterbrochen.
Zugleich wird der Forderung Rechnung getragen, dass in *erkrankte Gewebe*
niemals injiziert werden darf. Diese Umspritzung ist von Hackenbruch
erfunden. Sie ist aber vor Einführung des Novokains und Suprarenins
nur in sehr beschränkter Masse zu brauchen gewesen, sodass ihre
Technik erst in der neueren Zeit ausgebildet worden ist. Hierzu gehört
auch die Fingeranästhesierung nach Oberst.

Zur *Unterbrechung einzelner grösserer Nervenstämmen* (paraneurale und
endoneurale Injektion nach Matas) brauchen wir 1–4 prozentige NS.-
Lösung. Das Aufsuchen der Nervenstämmen mit der Hohlnadelspitze
ist leicht, wenn ihre Lage durch Knochenpunkte fixiert ist. Die beim
Berühren des Nerven mit der Nadelspitze entstehenden in die Peripherie
ausstrahlenden Parästhesien bilden einen sehr wichtigen Anhaltspunkt
für die richtige Lage der Nadel.

In der Praxis werden die erwähnten Injektionsmethoden meist
kombiniert. Wir führen sämtliche Injektionen tunlichst vor Beginn
der Operation aus und suchen stets das ganze in Betracht kommende
Operationsfeld auf diese Weise primär unempfindlich zu machen, sodass
weitere Injektionen während der Operation nicht mehr erforderlich sind.
Die Anästhesierung ist also nicht mehr ein Bestandteil der Operation,
sondern ein von ihr völlig getrennter, ihr vorangehender Vorgang.

*Jeder Körperteil und jedes Operationsfeld hat eine besondere, der sensi-
blen Innervation angepasste Anästhesierungstechnik.* Es ist daher völlig

ausgeschlossen, in dem Rahmen eines kurzen Vortrags etwas Anderes zu geben, als eine Uebersicht über die *Ergebnisse* der neueren Methoden.

Am *behaarten Kopf und der Stirngegend* führt die einfache ringförmige Infiltration des subgalealen Gewebes bez. der Muskeln, soweit solche den Schädel bedecken, um das ganze Operationsfeld herum mit 1 prozentiger NS.-Lösung eine vollständige Anästhesie nicht nur der Haut, sondern auch des Periosts und Knochens herbei. Die Dura ist nur an der Schädelbasis, das Gehirn nirgends schmerzempfindlich. Man kann deshalb fast alle Schädel- und Hirnoperationen in Lokalanästhesie ausführen, auch die Kleinhirnoperationen. Infolge des Suprareninegehalts der injizierten Lösung wird das Operationsfeld zugleich anämisch, sodass alle anderen Methoden der provisorischen Blutstillung überflüssig geworden sind.

Die *Operationen im Bereich des Gesichtsschädels* erfordern die Unterbrechung eines oder mehrerer Trigeminstämme an der Schädelbasis. Sie ist vom Referenten zu einer typischen Anästhesiemethode ausgearbeitet worden, welche die Narkose bei Operationen in diesem Gebiet so gut wie vollständig überflüssig macht. Ihre Technik ist dann durch die Einführung der Alkoholinjektion nach Schlösser gefördert und endlich von Härtel eine zuverlässige und leicht zu lernende Methode gefunden worden, um die Hohnadel in das Ganglion Gasseri einzuführen, sodass man nun durch Injektion von 1–2 ccm 2 prozentiger NS.-Lösung die eine Gesichtshälfte für die Zeit von 1–2 Stunden unempfindlich machen kann. Neben der Unterbrechung der Trigeminstämme sind stets noch Umspritzungen und Infiltrationen der Weichteile des Gesichts, der Schleimhaut des Gaumens und Rachens, des Zungengrundes nötig, teils um die Innervation von der anderen Seite und von benachbarten Nervengebieten auszuschalten, teils zur Gewinnung der hier ganz besonders wichtigen Suprareninanämie.

Die Radikaloperationen bei Eiterungen der Stirnhöhle und Oberkieferhöhle, die Oberkieferresektion, die Operationen wegen Tumoren des Nasenrachenraums mit ihren Voroperationen, die temporären und definitiven Unterkieferresektionen, die Operationen wegen Karzinomen der Zunge und der Tonsillengegend haben durch diese Art der Lokalanästhesie ein vollständig verändertes Ansehen bekommen. Sie sind sämtlich sehr leicht und spielend, sauber und ohne Blutung ausführbar, wie es in ähnlicher Weise bisher nicht möglich war. Voroperationen, wie die Tracheotomie oder die Carotisunterbindung, sind nicht mehr notwendig. Die unmittelbare Gefahr aller dieser Operationen und die Gefahr der Schluckpneumonien ist wesentlich verringert.

Welchen Siegeszug die Lokalanästhesie im Gebiet der *Zahnheilkunde* durch die ganze Welt angetreten hat, ist Ihnen allen bekannt. Die Zahnärzte haben die vom Referenten im Jahre 1905 beschriebene Technik übernommen, haben sie nach ihren speziellen Bedürfnissen ausgebaut und wissenschaftlich begründet, ohne ihr etwas wesentlich Neues hinzuzufügen.

Auch bei den *Halsooperationen* hat die Lokalanästhesie sehr grosse Fortschritte gemacht, weil man leicht mit 150 ccm $\frac{1}{2}$ prozentiger NS.-Lösung die ganze Vorderfläche des Halses mit allen dort befindlichen Organen unempfindlich machen kann. Man infiltriert zu diesem Zweck beiderseits vom Warzenfortsatz nach abwärts eine *bis auf die Querfortsätze* der Halswirbelsäule reichende Gewebsschicht, wodurch die Zweige des Plexus cervicalis unterbrochen werden. Es folgt subkutane und subfasciale Umspritzung oben entlang dem unteren Rande des Unterkiefers, unten quer über den Hals oberhalb des Jugulums. Auf diese Weise lassen sich alle, auch die kompliziertesten und langwierigsten Operationen am Halse ausführen. Bei einseitigen Operationen (Strumektomie) brauchen die Cervikalnerven nur einseitig unterbrochen zu werden. Im übrigen wird der Tumor umspritzt.

Kappis (Kiel) hat nach Analogie der Trigemiusanästhesie die Interkostalnerven und Lumbalnerven unmittelbar an ihren Austrittsstellen aus der Wirbelsäule unterbrochen und nennt dieses Verfahren 'paravertebrale Leitungsanästhesie'. Da aber die Injektion des Anästhetikums an dieser Stelle wegen der Möglichkeit des Eindringens in den epiduralen und subduralen Raum nicht ganz gefahrlos ist, empfiehlt es sich, die Unterbrechung dieser Nerven lieber in einiger Entfernung von den Austrittsstellen vorzunehmen.

Bei den *Operationen am Brustkorb* ist die Unterbrechung der Interkostalnerven das Wesentliche der neueren Technik. Man führt sie je nach Bedürfnis in verschiedenem Umfange und in Verbindung mit Umspritzungen und Infiltrationen entweder in der Nähe des Operationsfeldes oder nahe an der Wirbelsäule aus und kann leicht eine ganze Thoraxhälfte auf ein Mal unempfindlich machen. Um die Ausbildung dieser Methoden haben sich mehrere jüngere deutsche Chirurgen (Hirschel, Franke, Kappis, Schumacher) verdient gemacht.

Die Operationen des *Mammakarzinoms* führe ich regelmässig in Lokalanästhesie aus, u. zw. ebenso bei fetten, wie bei mageren Personen. Es wird hierzu zunächst der Plexus brachialis oberhalb des Schlüsselbeins nach Kulenkampff unterbrochen, ferner werden der 1. bis 8. oder 10. Interkostalnerv neben der Wirbelsäule unterbrochen. Endlich wird ein Streifen subkutan infiltriert, der am Akromion beginnt, der Clavicula folgt, in der Mittellinie des Sternums herabläuft und am unteren Rande des Brustkorbs nach hinten umbiegt. Es tritt dann vollständige Anästhesie des ganzen grossen Operationsfeldes ein. Die bisherigen Versuche, das Mammakarzinom in Lokalanästhesie zu operieren (Hirschel, Chaput, Hohmeier u. a.) halte ich für verfehlt, weil ich Injektionen in die Nähe der karzinomatös erkrankten Mamma und in die erkrankte Achselhöhle nicht für zulässig halte.

Von den *Bauchoperationen* sind viele Hernien seit langer Zeit von *einzelnen* Chirurgen in Lokalanästhesie ausgeführt worden. Unsere Anästhesietechnik besteht in perkutaner Unterbrechung des N. ileoinguinalis und ileohypogastricus an der Spina ilei ant. sup. in Verbindung

mit Injektionen in den Samenstrang und subkutaner Umspritzung des ganzen Operationsfeldes. Sie hat zur Folge gehabt, dass die Hernienoperationen nun fast allgemein in Lokalanästhesie ausgeführt werden. Für die Güte der letzteren spricht, dass wir selbst die Kinder bis herab zu 4 Jahren in Lokalanästhesie operieren können.

Von sonstigen wesentlichen Fortschritten der Lokalanästhesie bei Bauchoperationen ist nicht viel zu berichten. Die *Magenoperationen* werden vorteilhaft nach Anästhesierung der Bauchdecken in Verbindung mit Narkose ausgeführt. Ob man mit der paravertebralen Leitungsanästhesie nach Kappis hier noch weiter kommt, muss die Zukunft lehren.

Besser, als man meinen sollte, sind für die Lokalanästhesie die *Nierenoperationen* geeignet (Läwen, Kappis). Ich konnte nach Unterbrechung des 8.–12. Interkostalnerven und 1.–3. Lendennerven in reiner Leitungsanästhesie Steinoperationen und Nephrektomien ausführen.

Bei den Operationen an den *Organen des kleinen Beckens* (Genitalien, Harnorgane und Mastdarm) sind von neueren Methoden die Versuche bemerkenswert, diese Organe im Ganzen durch Leitungsanästhesie unempfindlich zu machen. Franke und Posner sind dabei so vorgegangen, dass sie NS.-Lösung zwischen Mastdarm und Prostata bzw. Vagina und an den Stamm des N. pudendus injizierten, da, wo er der Spina ischiadica aufliegt. Ich selbst bediene mich eines anderen Verfahrens, welches darin besteht, dass beiderseits je 50 ccm 1 prozentige NS.-Lösung an die fünf vorderen Sakrallöcher injiziert werden. Ich nenne dies Verfahren in Anlehnung an die Injektionen an die Vertebrallöcher *parasakrale Leitungsanästhesie*. Sie bewirkt eine vollendete Anästhesie der Beckenorgane und reicht nicht nur für die Operationen an der Prostata, Blase und Harnröhre, sowie den äusseren weiblichen Genitalien aus, sondern auch für die Exzision von Analkarzinomen und die sakrale Resektion hochsitzender Rektumkarzinome.

An den *Extremitäten* hat die schon 1885 von Conway geübte Anästhesierung der Frakturen und Luxationen durch Injektion eines Anästhetikums zwischen und um die Bruchenden oder in das luxierte Gelenk dank der Empfehlung von Lerda und Quénu weitere Verbreitung gefunden. Bei den Knöchelbrüchen und Luxationen an der unteren Extremität ist sie ein sehr nützliches und gutes Verfahren. Ich konnte sogar eine frische Luxatio ischiadica und eine Luxatio obturatoria femoris nach Injektion von 40–50 ccm 1 prozentiger NS.-Lösung spielend leicht und ohne Schmerzen reponieren.

An der *oberen Extremität* führt die von Kulenkampff angegebene Unterbrechung des Plexus brachialis über dem Schlüsselbein eine vollständige sensible und motorische Lähmung des Arms herbei. Die Unterbrechung geschieht durch Injektion von 20 ccm 2 prozentiger NS.-Lösung an die Stelle, wo der Plexus neben der A. subclavia der 1. Rippe aufliegt. Auf diese Weise sind also alle blutigen und unblutigen Operationen am Arm, und wenn man die Injektion mit lokalen Umspritzungen und

Infiltrationen verbindet, auch die Operationen am Schultergelenk der Lokalanästhesie zugeführt.

An der *unteren Extremität* sind weitere Versuche gemacht worden, die perkutane Unterbrechung der auf das Bein übertretenden Nervenstämme (N. ischiadicus, femoralis, cutaneus femoris lateralis und posterior, obturatorius) mit Hilfe der neuen Mittel zuverlässiger als bisher zu machen (Nyström, Læwen, Perthes, Keppler), um auf diese Weise, wie am Arm, eine Anästhesie der ganzen Extremität zu erhalten. Freilich liegen am Arm die Bedingungen hierzu viel günstiger, und ein Verfahren, welches so einfach und zuverlässig ist, wie die Unterbrechung des Plexus brachialis, wird sich an der unteren Extremität nicht ausbilden lassen.

Ich habe die gesamte Technik der lokalanästhetischen Operationen beschrieben in meinem Buch *Die Lokalanästhesie, ihre wissenschaftlichen Grundlagen und praktische Anwendung*, 3. Auflage, Leipzig, 1913.

SECTION VII (b)

ANÆSTHESIA, GENERAL AND LOCAL

DISCUSSION No. 2

RECENT METHODS OF GENERAL ANÆSTHESIA

REPORT BY DR. J. H. CUNNINGHAM, JR., BOSTON, U.S.A.

(b) RECTAL ETHERIZATION

THE first attempts to produce ether narcosis by the employment of ether in the rectum date back to within a few months of Morton's first demonstration of ether narcosis by inhalation. Mention of the procedure is made in a book by Pirogoff in 1847, the year following the first administration of ether. In this same year, Roux, Vincente y'Yhedo, and Marc Duprey independently employed injections of ether, pure and mixed with water, into the rectum, demonstrating the practicability of this method of producing complete narcosis.

In view of the brilliant achievements in producing anæsthesia by inhalation, the rectal method did not gain in popularity, and no mention of the procedure appears again until 1884. In this year, Mollerie, at the suggestion of Dr. Alexander Yversen, of Copenhagen, employed the method at the Hotel Dieu de Lyon. The work of Dr. Yversen stimulated others, and Hunter reported a series of six cases in the *Medical Record* in 1884, in which he employed the method satisfactorily. In this same year Dr. Weir and Dr. Bull, of New York, employed the method in seven cases, and reported their results in the *New York Medical Record*. Wanscher, following the original method of Pirogoff, published a series of twenty-two cases in which he had employed the method satisfactorily. Dr. Abner Post practised the method in the Boston City Hospital, and published his results in the *Boston Medical and Surgical Journal*.

The practice of producing anæsthesia by the rectal method was again discarded chiefly on account of the fact that bloody diarrhœa often accompanied the procedure, although it was again demonstrated that complete and satisfactory narcosis could be produced. So far as the writer can learn, rectal anæsthesia was not practised between the years 1884 and 1903.

In the years 1902 and 1903 there were many cases at the Boston City Hospital which were receiving rectal feedings. Ignorant of the successful employment of ether in producing anæsthesia through the rectum, the writer conceived the idea that a vapour might be absorbed from the rectal wall in somewhat the same manner as the liquids.

Mention of this to Dr. Post, at that time one of the senior surgeons at the Boston City Hospital, resulted in the writer being enlightened with regard to the early work just mentioned. From a perusal of the methods already employed, it was believed that the chief objection to the method (the bloody stools and rectal irritation) was due to the effect of pure or diluted ether upon the mucous membrane of the gut. An apparatus was therefore constructed which would allow the introduction of ether-laden air only. The apparatus was employed at the Boston City Hospital and the Long Island Hospital, Boston, in many cases without the untoward effects which frequently accompanied the old method. The procedure was tried by others, and its practicability has been demonstrated. This method of ether administration may serve as a special method to be employed in two groups of cases, namely, those in which the presence of the ether cone over the face hinders the performance of the operation, but more especially in those cases in which there is a diseased condition of the lungs.

It is obvious that a free and continuous access to the field of operation is a great advantage to the surgeon. In all operations about the head and neck, the absence of the ether cone not only lessens the technical difficulties of the operation, but minimizes the chances of sepsis, and lessens considerably the time necessary to perform the operation. Other recent methods of narcosis, perhaps, accomplish this in a simpler manner.

The employment of this method of etherization in diseases of the lungs, especially tuberculosis, abscess, pneumonia, empyema, mediastinal abscesses, and new growths, immediately suggests itself, and has proved to be all that could be desired. It is in this class of cases that rectal ether has its special value over other methods of general anæsthesia.

Although it is true that the greater part of the ether is eliminated through the lungs, as in inhalation narcosis, the direct irritation of the concentrated vapour is overcome, and post-operative pneumonia has not developed in a single case so far as the writer can learn. In this connexion a patient operated upon by the late Dr. Walter Lecompte, of Boston, is of interest. This patient had a lobar pneumonia. He also developed a mastoid abscess requiring operation. The operation was performed under rectal anæsthesia administered by Dr. Freeman Allen. Resolution in the lung took place at the proper time, and the pneumonia process did not seem to be aggravated in any way.

By the old method of administration there were distinct disadvantages which caused it to be discarded. These were rectal disturbances and the inability to control the stages of narcosis.

The rectal irritation is easily explained when we consider the old method of administration, which was to place a bottle of ether in a boiling-water bath and to allow the vapour to be carried over into the rectum by its own expansion. By this method there was no means of appreciating the amount of ether gas passing into the rectum, and the vapour

going over at a high temperature was condensed in the efferent tube and rectum, thus producing an irritation.

Colicky pains and painful distension, which sometimes occurred as after effects, have been noted in a few cases with the new method, but the pain has been so slight and has passed off in so short a time in most cases, that it can hardly be considered a disadvantage. This pain has been noted more particularly in those cases in which the bowel has not been properly prepared for the anæsthetic.

It is not desirable to employ the method in abdominal cases, on account of distension of the intestines. In four cases in which the abdomen has been opened by the writer when this method of anæsthesia was employed, the small intestine as well as the large gut was found distended. This same observation has been made by others. A large amount of animal experimentation has shown the same thing.

The method should never be employed when a diseased condition of the intestines is known to exist, and inquiry should always be made regarding this point, for if ulcers or diseases are present which weaken the intestinal walls, perforation of the gut might result. Anschütz and Baum found a perforation of the cæcum at autopsy in a patient who died from peritonitis twenty-four hours after an operation, conducted under rectal anæsthesia, and the writer had a death from rupture of an old amoebic dysentery ulcer in which he operated for carcinoma of the lip.

Technique. To obtain the best results it is essential that the *bowels should be thoroughly cleaned out*. It has been our custom to give two ounces of a saturated solution of magnesium sulphate on the evening before operation, and early the next morning a large suds enema. Just before going to the operating-table another similar enema is given, and care taken that it returns.

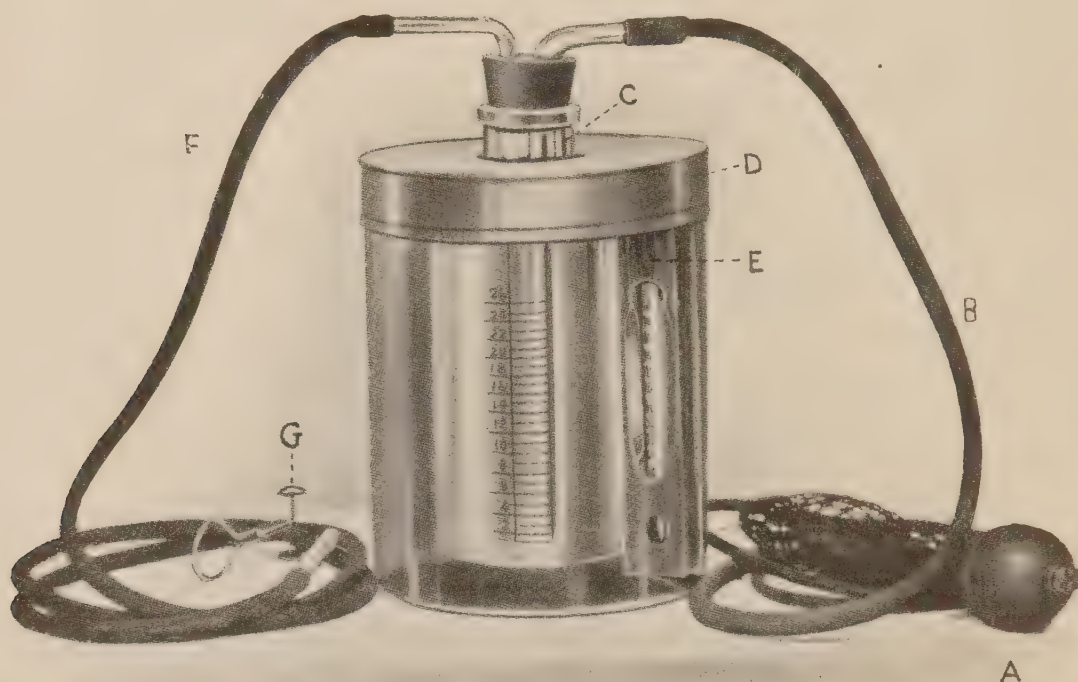
The ether breakfast has consisted of two ounces of beef-tea.

We began our experiments with a wash-bottle six inches in height and two and a half inches in diameter. Of the height four inches were used for ether space and two inches for vapour space. A simple straight glass tube led to the bottom of the bottle, and was connected with the efferent tube. The efferent tube leading to the rectum was connected with a glass tube, the proximal end of which was flush with the inner surface of the rubber stopper. This was a satisfactory apparatus except that the bottle did not hold enough ether without refilling during a long operation. Later, we tried an apparatus in which the wash-bottle was twelve inches in height and one and a half inches in diameter, allowing a nine-inch column of ether for the air-bubbles to ascend through. This was discarded, as it was difficult to keep the apparatus in an upright position, and the small amount of ether used rapidly cut down the height of the column, owing to its small diameter.

Later, the Davidson apparatus, which is used to administer warm ether vapour through a hard rubber tube in the corner of the mouth, was tried, and was discarded, because of the foot-pump and the stop-

valve in the efferent tube, the foot-pump filling the bag, which caused a constant flow of ether when the stop-valve was opened. In administering the anæsthetic in this way, it is impossible to appreciate as accurately the amount of ether being given as with a hand-bulb.

The apparatus which we have used on all our later cases, and which has been the most satisfactory, consists of a bottle, the body of which is seven and a half inches in height, five inches being used for ether space; two and a half inches and the neck for vapour space. The diameter is four inches, and the capacity of the ether space twenty-nine ounces, so that a large amount of ether may be used without materially lowering the ether column. The efferent tube which leads to the bottom of the



A. Bulb. B. Afferent tube leading to bottom of ether bottle c. c. Ether bottle. D. Jar containing water at 80° F. in which ether bottle c is immersed. E. Thermometer. F. Efferent tube. G. Snap to prevent reflow of gas into ether bottle.

ether column ends in a glass bulb with several small perforations, so that the air is broken up and ascends in small bubbles. The stopper and the connexions should be tight. (See illustration.)

The bottle is placed in a water-bath at a temperature of between 80° and 90° F. *Ether boils at 98.6° F. It is desirable to keep the temperature below this point.* By keeping the ether as warm as possible, without boiling, the air forced in by the bulb is more easily saturated. If the operation is a long one it may be desirable to renew the temperature of the bath. We have employed all makes of ether and the results have been the same. The inexpensive ether has been quite as satisfactory as the most expensive.

The efferent tube should be sufficiently long to allow moving the wash-bottle away in case the operator wishes to change his position

from one side of the table to the other. We have tried efferent tubes of varying lengths, and have noticed no difference in the results, ether in no case being condensed in the efferent tube.

The efferent tube should be of sufficient length to allow the etherizer to inspect the patient from head to foot, still retaining the bulb in hand. We have not found it necessary to employ an 'interceptor', as no ether is condensed in the tube.

We have tried rectal tubes with eyes placed at various intervals; we have also used a Y-tube in connexion with the rectal tube and with return-flow catheter to allow the escape of gas when desired, but these only serve to complicate the apparatus. A clamp on the efferent tube is of advantage to prevent the reflow of ether into the bulb when there is pressure in the rectum and ether bottle.

Legueu, Morel, and Verliac, in an article in the *Archives générales de Chirurgie*, June-July, 1909, have described a modification of the apparatus, by employing a bottle of water in the efferent tube for the ether to pass through, and a safety exit for intestinal gases and fluids. They also employ a Y-tube, as we did in an early apparatus. There are many such details which may suit the individual conception of what the apparatus should be, but we have attempted to avoid all devices which complicate the apparatus. Many of these accessory features employed by others have been tried and discarded. The aim has been to make a simple serviceable apparatus to which may be added whatever the individual may consider advantageous.

During the administration the patient lies upon the back or in a sitting position, with the legs held in slight flexion by a sand-bag placed under the thigh. A stiff, large-sized catheter or rectal tube is inserted into the rectum for a distance of from ten to fourteen inches. When there is difficulty in placing the tube because of kinking, a bougie is introduced into the rectal tube, and withdrawn after the tube is in place. The efferent tube is now connected with the rectal tube, and the vapour forced into the rectum by squeezing the bulb until considerable gas is passed around the rectal tube. Keeping the forefinger in the rectum beside the tube, unless it causes the patient pain, hastens the expulsion of the intestinal gases. A Y-tube or a double catheter may be used for this purpose if so desired.

It is essential that the rectum be distended to the point of emptying itself around the tube, for we have learned that without first removing the gas normally in the bowel, the patient absorbs the ether much more slowly, presumably because of the dilution of the ether gas by the gases normally in the gut. After this gas has been expelled the ether vapour should be forced in by a few squeezes of the bulb every five to ten seconds, or until it is expelled around the tube. At the first introduction of the rectal tube, or the first volume of ether, the patient may feel discomfort and desire to defæcate; but in a short time this sensation disappears. The breath becomes ether-laden in from one to five minutes after the ether is started. The patient gradually becomes drowsy, the breathing

stertorous, and then passes into complete surgical narcosis without any stage of excitement.

Narcosis being complete, the same signs regarding the patient's condition should guide the anæsthetist as in administering ether by inhalation. Care should be exercised after complete narcosis has taken place that the jaw does not drop down, allowing the tongue to fall back over the larynx. In one of our early cases the patient became partially asphyxiated through neglecting this precaution. When the jaw was drawn forward the natural colour returned to the face, and the patient began to breathe normally. The jaw muscles become relaxed in this form of anæsthesia, as in any other.

After narcosis is complete, two or three squeezes of the bulb a minute will usually suffice to keep it so. It is noteworthy that the patients may be 'run light' as they usually respond rapidly to the injections after being once under the influence of the drug. In fact it has been our custom to allow the patient to give evidence of recovering, and then to put them under again.

If the patient becomes too profoundly anæsthetized, the efferent tube should be disconnected, and such ether gas as is in the bowel forced out through the rectal tube by abdominal massage. An oxygen tank should be connected with the rectal tube, and this gas made to distend the bowel. Artificial respiration and stimulation should be resorted to in the usual manner. Personally, I have never known this to be necessary. It is only stated as a precaution. Legueu, Morel, and Verliac advise the use of oxygen with the ether vapour, and assert that they obtain in this way an excellent anæsthesia, with a more normal maintenance of cardiac and pulmonary function.

Arnd recommends the employment of a 5 per cent. solution of ether in water after a previous administration of a dose of scopolamine and pantopon.

Morel mentions experimental work employing ethyl bromide in dogs, cats, and rabbits with unsatisfactory results, narcosis not being satisfactorily produced. Experiments with chloroform have been likewise unsatisfactory.

The experimental work of Leggett, Churchill, and others has shown that dogs do not pass readily under the anæsthetic administered by this method: presumably because of the small colon.

While it is possible to produce ether narcosis by the rectal method, it has been our custom in most cases to start the anæsthesia by inhalation; as often the passage of the rectal tube and the first introduction of the vapour are disagreeable to the patient. The primary stage is reached by inhalation, and then the rectal tube may be passed and the vapour introduced without discomfort.

When the operation has been completed it has been our custom to expel as much of the gas as possible by massage of the abdomen with the rectal tube still in position.

Experience has shown that patients given rectal ether, uncombined with inhalation methods, usually complain of abdominal distension at the beginning. They pass under the influence of the drug rapidly in some instances, but usually in from ten to twenty-five minutes; there is no sense of suffocation; less ether is used, not only in producing the narcosis, but also in maintaining it; the stage of excitement is lessened or absent; bronchial secretions are absent; the ether recovery is rapid; the disagreeable after-effects of inhalation ether narcosis are diminished or absent. Especially is this true of vomiting. Vomiting is very rare indeed if only rectal ether is given.

Theory regarding the Physiology of Ether Narcosis by Rectal Administration. At the outset it is necessary to allude to the law of partial tension upon which the physiology of ether narcosis is based.

The Law of Partial Tension. When ether or almost any other gas (excepting oxygen) is inhaled, it passes through the walls of the alveoli into the blood circulation until the blood circulation contains the same quantity of the gas as the air in the alveoli. When the percentage of the gas is decreased in the air of the alveoli by respiration, then the gas will pass back from the blood into the air in the alveoli, until the air of the alveoli contains the same percentage of the gas as the blood. There is no reason to believe that the law of partial tension holds true when ether is administered by the rectum, nor is there any known scientific explanation of the phenomenon of ether narcosis produced by this method of administration.

A theory advanced by Dr. M. Vejux-Tyrode, of the Pharmacological Department of the Harvard Medical School, who was kind enough to study our early cases, is briefly as follows:—‘First, a definite percentage of ether must be present in the entire circulation to produce a complete surgical anæsthesia. In human beings this amounts to a little under six volumes per cent. The rapidity with which complete narcosis results depends upon the rapidity with which the proportion of ether is brought up to nearly six volumes per cent. When ether is given by the lungs in the form of vapours it can only be administered in great dilution unless excretion be interfered with, and the proportion in the blood be raised above six volumes per cent., which would prove fatal by paralysis of the respiratory centre in the medulla. On the other hand, when ether is administered by the rectum as a vapour, concentrated vapours may be given. Therefore, the chances for the rapidity of absorption and the raising to six volumes per cent. will take place more rapidly, while excretion may take place freely from the lungs.’

This is an explanation for the rapidity with which certain of our patients have become anæsthetized, some being completely under the influence of the drug in five minutes. Most cases require from ten to fifteen minutes, some longer. Theoretically, fatality is less likely to result as the lung is free to eliminate ether as fast as it is absorbed from the rectum. On the other hand, Legueu, Morel, and Verliac state that

cardio-respiratory disturbances are not infrequent. They attribute collapse to a sudden yielding of the ileocæcal valve, allowing the ether gas to rush suddenly into the small gut and there become rapidly absorbed, resulting in an overdose of the drug. They contend that anæsthesia produced by inhalation before the rectal administration is begun results in a relaxation of the ileocæcal valve, and the gas then passes gradually into the whole intestinal canal from the beginning, and not suddenly. They advise the use of the ethyl bromide before the rectal ether is begun, in order to bring about the relaxation of the ileocæcal valve.

From my knowledge of rectal anæsthesia, as practised by the modern method, cardio-respiratory disturbances are rare, and mention of it is made only in the article by Legueu, Morel, and Verliac. In an article published in the *Boston Medical and Surgical Journal*, September 12, 1907, I laid special stress on the cases which had died following the administration of ether by the rectum.

At that time I reported two deaths occurring in personal cases, one a blind boy, six years old, with constitutional tuberculosis, upon whom a prolonged operation was performed for tuberculous adenitis in all the triangles of the neck. The anæsthesia was excellent for about two hours, when the pulse became gradually rapid and of poor quality, and respiration shallow and laboured. This patient failed to rally, and died. The cardio-respiratory symptoms were not sudden as suggested by Legueu, Morel, and Verliac, and the picture did not differ from surgical shock. Autopsy showed tuberculosis of the lungs and the abdominal organs.

The other fatal case was that of a woman, 63 years old, upon whom an extensive operation for cancer of the neck was performed. This patient was also under ether over two hours. In this individual the cardio-respiratory symptoms were gradual. This patient, however, had several faecal and gaseous movements, and the abdomen was much distended. Death took place on the second day following operation.

Since that time we have had three other fatal cases, all aged persons with carcinoma, one an elderly woman upon whom I had operated for carcinoma of the uterus, and in whom four months later large, painful carcinomatous glands developed in both sides of the neck. This operation was also of long duration, and the cardio-respiratory symptoms developed gradually, death occurring a few hours after operation. The abdomen, however, was not distended. Autopsy showed diffuse abdominal and plural carcinoma.

Another patient was a man upon whom I operated for carcinoma of the tongue, in which operation the whole tongue, the right tonsil, and soft palate, together with cervical nodes were removed. In this patient cardio-respiratory symptoms developed gradually, and the abdomen was not distended following the operation. The picture was that of a surgical shock, the patient living eight hours after the operation. The only death that can justly be attributed to the methods was a man fifty-four years old, who was operated upon for carcinoma of the lip, and

died from an intestinal perforation in an old amœbic ulcer of the bowel. A report of this was published in the *Boston Medical and Surgical Journal*, March 24, 1910.

In mentioning these fatal cases, one cannot help but feel that except for the case with amœbic dysentery, the physical condition of the patient and the severe character of these operations, together with the picture following operation, places them rather in the class of surgical shock than collapse. What would have been the result had these patients been etherized by the usual method, of course, cannot be told, yet in each instance the condition of the patient was such that extensive operations might well have been considered inadvisable. It was only in view of the fact that several such patients, considered inoperable if subjected to the usual form of etherization, had recovered, in our opinion chiefly because of the advantage of a more rapid operation made possible by rectal anæsthesia, that these operations were undertaken at all. It seems fair to consider it an error in judgement to have subjected these patients to any form of anæsthesia, and not to condemn the rectal method, as there were no symptoms differing from those accompanying the usual forms of anæsthesia in similar patients.

There is a point of scientific interest in regard to vomiting to which this method of etherization has added valuable evidence. There are two theories offered to explain the vomiting which usually follows ether narcosis: one, stimulation of the vomiting centre in the brain just as with apomorphine; the other, a reflex stimulation due to the local irritant action of the swallowed ether-laden saliva on the mucosa of the stomach. Our experiments are rather in favour of the latter theory, because we obviate to a considerable extent the swallowing of ether laden saliva, and the cases etherized entirely by the rectal method failed in the great majority of cases to show vomiting as an after-effect. If the former theory is true, there is no reason to expect any difference in the amount of vomiting between the two methods of administration, as the same amount of ether must necessarily reach the central nervous system.

While the history and the development of technique of this procedure are interesting, the real point of importance is whether or not this method of ether administration is attended with greater danger to life or after-effects which outweigh its advantages.

The writer is unable to answer this question positively, because of a limited personal experience. The published experience and a personal knowledge of the work of others have, on the whole, been of a most favourable character, but one is not positive that unfavourable results may have existed which have not been made public.

Besides the original publication made by Dr. Lahey and myself (*Boston Medical and Surgical Journal*, April 20, 1905), and the publication, two years later, by the writer, Leggett (*Annals of Surgery*, October 1907) recorded thirty-one cases, thirteen of which he etherized at the Roosevelt Hospital, New York, for Dr. Brewer, Dr. Blake, Dr. Martin,

and Dr. Flint. He also records eighteen cases through the courtesy of Dr. W. S. Sutton, of the Roosevelt staff. His remarks are entirely favourable, and are as follows: 'The lessening of nausea, the lessening of irritation to the lungs, and the lessening of the bronchial secretions which were nearly entirely absent in most of the cases, are certainly all in themselves favourable. Furthermore, a fully and continuously clear field of action in all operations about the head and neck, saving time and loss of blood, and above all lessening the chance of infection from an ether cone, are all points in favour of the method which must appeal to every operating surgeon.'

Leggett also did considerable animal experimentations, and found that when the gas was made to pass the ileocæcal valve complete narcosis could be maintained for any length of time; also that the dogs had no rectal disturbances. Leggett, in his article, justly remarks that the method 'has its uses and abuses'.

Dumont, at Berne (*Correspondenz-Blatt für schweizer. Aerzte*, 1903, 1904, and December 15, 1908), in 1903 employed the method satisfactorily in four cases, and recommends its use in head and neck cases.

A later publication (*Correspondenz-Blatt für schweizer. Aerzte*, No. 24, pp. 785-816, December 15, 1908) in 1908, after further trial of the method, still makes most favourable comments upon its use.

Kadjan, of St. Petersburg, employed the method in sixty-eight cases which have been recorded by Anna Morosow (*Zentralblatt für Chirurgie*, 1909, No. 2). This series consists of sixty-eight cases. There were no deaths, and it is stated that sixty-one patients slept perfectly, five were restless at times during the operation, and in two satisfactory narcosis could not be produced. Eight of the patients had loose movements following the operation, and one, a patient, 75 years old, had loose movements containing considerable blood.

Baum, of Kiel (*Zentralblatt für Chirurgie*, May 13, 1909), performed rectal anæsthesia in eight cases with a slight modification of the old Pirogoff apparatus, and not with the improved technique. Five of his cases were satisfactory, one patient had rectal hæmorrhage, and one died from peritonitis caused by intestinal perforation due to the existence of ulcerations in the intestine. These results are hardly better than those of the early experiments with the Pirogoff apparatus of 1847.

Dr. Stucky, of Lexington, Ky. (*Journal of the American Medical Association*, July 28, 1906), reports four cases in which he employed rectal anæsthesia, and speaks in favourable terms regarding it. In a letter to me he states: 'I found it hard to overcome professional prejudice against the method, but I am so pleased with the results that I propose to continue it.'

Dr. Lumbard, of New York (*Medical Record*, December 1, 1906), records four cases, with the comment that in each instance the gas had passed the ileocæcal valve, and the small gut was inflated throughout its whole length.

Dr. Denny and Dr. Robinson, of St. Paul (*Journal of the Minnesota State Medical Association*, February 1, 1909), recorded ten cases with excellent results.

Legueu, Morel, and Verliac (*Archives générales de Chirurgie*, June-July 1909) have done a large amount of experimental work on rectal anæsthesia, and stated that when the administration is properly performed in suitable cases, this method of anæsthesia is no more dangerous than inhalation narcosis.

Krougiline (*Wiener klinische Wochenschrift*, December 1904) records forty-three cases without any untoward symptoms. He emphasizes the importance of preparation of the bowels, and keeping the ether below the boiling-point.

Churchill, of Chicago, Illinois, employed the method in forty-seven patients, with unsatisfactory results in five patients, and states that in four of these five there was failure to keep the patients under the anæsthetic because of insufficient preparation of the bowel, and in the other the apparatus was defective. In the remaining forty-two patients the narcosis was satisfactory in every respect.

Sutton states that there was no mortality in a series of 140 cases at the Roosevelt Hospital, N.Y.; and Dr. O. J. Cunningham, Kansas City, Mo., in a report prepared for the Anæsthetic Commission of the American Medical Association, makes the statement that rectal anæsthesia has been employed in 15,000 cases without a fatality.

In closing, the writer desires to emphasize the fact that this form of narcosis has always been, in his mind, a method for special cases, and it is hoped that an expression of opinion of those present will place this method of producing ether narcosis where it belongs in relation to other special methods employed in the same special group of cases.

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SUB-SECTION VII (b)

ANÆSTHESIA, GENERAL AND LOCAL

DISCUSSION No. 2

NEUE METHODEN ZUR ANWENDUNG DER ALLGEMEINEN ANAESTHESIE

REFERAT VON PROFESSOR DR. L. BURKHARDT, NÜRNBERG

(c) INTRAVENÖSE METHODE

DIE der Inhalationsnarkose anhaftenden, bald mehr bald weniger hervortretenden Uebelstände

I. die Reizung der Luftwege und reflektorische Reizung des N. vagus und trigeminus mit ihren Folgezuständen,

II. die Unbequemlichkeit und Gefährdung der Asepsis bei Operationen am Kopf und Hals,

III. die mit dem Einatmen des Narkotikums verbundenen subjektiven Unannehmlichkeiten und Nachwirkungen, werden vermieden, wenn man das Narkotikum auf dem Wege der intravenösen Injektion dem Organismus zuführt. Für die Allgemein-Narkose haben sich bisher die flüchtigen Narkotika der Fettreihe am besten bewährt. Auf ihrer Anwendung beruhen die Vorzüge der Inhalationsnarkose: die leichte Dosierbarkeit der Narkose und die rasche Wiederausscheidung des Narkotikums aus dem Organismus.

Nach den Ergebnissen der Tierversuche erfolgt die Narkose bei intravenöser Injektion wässriger Chloroform- oder Aetherlösungen in derselben Weise, wie bei Inhalation des Narkotikums. Die Verteilung desselben im Blute bezügl. die Bindung an die roten Blutkörperchen ist, ebenso wie der Chloroform- und Aethergehalt des Blutes und Gehirnes, bei beiden Methoden ganz gleich, Atmung und Blutdruck werden während der intravenösen Narkose fast gar nicht beeinflusst. Ein Teil des injizierten Chloroforms bezügl. Aethers verlässt bereits beim Passieren des kleinen Kreislaufes in den Lungen wieder den Organismus, ehe es in den grossen Kreislauf gelangt ist. Sowohl die Ausscheidung des Narkotikums wie auch die Erreichung des Toleranzstadiums erfolgt bei der intravenösen Narkose rascher als bei der Inhalationsnarkose. Die Narkose ist daher bei der intravenösen Methode noch leichter zu unterbrechen und wieder zu vertiefen.

Intravenöse Narkosen beim *Menschen* mit konzentrierten *Chloroform-*lösungen, welche 0,97 Prozent Chloroform enthalten, verursachten bei

etwa der Hälfte der Fälle Hämoglobinurien und zum Teil Reizungen der Nieren, die allerdings nach ein bis zwei Tagen wieder abgeklungen waren. Der Verlauf der Narkosen war ruhig, ohne jede Störung und Nachwirkung. Dieselben Erfahrungen machten italienische Autoren.

Geeigneter für klinische Zwecke ist die intravenöse *Aethernarkose*, die wir zur Zeit bei über 600 Patienten ausführten. Zur intravenösen Injektion eignet sich am besten eine 5 *Volum* prozentige Lösung, die auf 30 Grad erwärmt ist. Das Stadium der Toleranz wird nach 5–6 Minuten mit 250–400 ccm der Aetherlösung erreicht, wenn in der Minute 70–80 ccm der Lösung einfließen. Diese Einflussgeschwindigkeit ist nötig, da sonst die zur Toleranz nötige Aetherkonzentration im arteriellen Blute nicht erreicht wird. Der Eintritt der Narkose wird beschleunigt, der Flüssigkeitsbedarf verringert, wenn man etwa 40 Minuten vorher eine Scopomorphininjektion in der üblichen Dosis gibt, was bei kräftigeren Patienten empfehlenswert ist.

Ernstere Störungen während und infolge der Narkose kamen nicht zur Beobachtung. Fünf mal wurde eine ganz leichte Asphyxie notiert, die stets rasch zu beheben war. Sie waren durch Ueberdosierung infolge zu schnellen Einfließens der Lösung entstanden. Aeusserst selten, nur im 15. Teil der Fälle, traten leichte Excitationserscheinungen auf und ebenso selten erfolgte nach der Narkose Erbrechen, das übrigens grossenteils infolge abdominaler Erkrankungen hervorgerufen war. Spätestens nach 30 Minuten wachten die Patienten klar auf, Kopfschmerzen und Uebelsein fehlten. Die Patienten konnten unmittelbar nach der Narkose, soweit dies die Erkrankung gestattete, essen und trinken.

In sechs Fällen war in den ersten Tagen nach der Narkose die Injektionsvene am Arme als verdickter Strang fühlbar. Alle letal endigenden Fälle sind obduziert worden. Eine Schädigung infolge der Narkose war nie zu konstatieren. Meist befand sich in der Injektionsvene flüssiges Blut, nur vier mal ein Thrombus bis zur nächsten Teilungsstelle.

Nierenschädigungen sind durch die intravenöse Aethernarkose, jedenfalls sofern die Organe vorher gesund waren, nicht zu befürchten. Bei drei Patienten fanden sich nach der Narkose Cylinder im Harn, bei sechs Patienten etwas Eiweis. In allen diesen Fällen war nach 24 Stunden der Harn wieder normal.

Höher konzentrierte als 5 Prozent Aetherlösung verursachen jedoch nach eigenen Erfahrungen leichte Nierenreizungen und Hämoglobinurien. Wir haben Hämoglobinurien im ganzen fünf mal beobachtet und führen sie, soweit sie bei Verwendung 5 prozentiger Lösungen entstanden, zurück auf mangelhafte Verteilung des Aethers in der Lösung, also auf einen technischen Fehler; eine solche Lösung enthält dann teils mehr teils weniger als 5 Prozent Aether. Von anderer Seite (Rood u. A.) wurden allerdings auch höher konzentrierte Aetherlösungen (7 und 8 Prozent) zur Narkose ohne Nachteil, speziell ohne folgende Hämoglobinurie verwendet. Es ist aber fraglich, ob nicht infolge der Erwärmung

der Lösung vor der Narkose auf 40 Grad, wie dies z. B. von Rood geschah, ein Teil des Aethers wieder verdunstete, sodass der Aethergehalt der Lösung doch nur höchstens 5 Prozent betrug. Die Hämoglobinurien kommen dadurch zu Stande, dass während des Durchfließens der Aetherlösung von der Eintrittsstelle in die Vene bis in das rechte Herz eine gewisse Zahl roter Blutkörperchen aufgelöst wird. Hier ist relativ viel, d. h. mehr Aether mit dem Blute in Berührung, als nach dem Uebertritt der Lösung in das linke Herz. Die dabei aufgelöste Blutkörperchenmenge ist, wie Untersuchungen zeigten, eine ganz geringe und beträgt nur wenige ccm Blut, eine Schädigung der Nieren erfolgt durch die Hämoglobinurie nicht.

Zur Vermeidung von Thrombenbildungen und Embolien ist es nötig, nach dem Vorschlag der Kümell'schen Klinik möglichst dauernd Flüssigkeit während der ganzen Narkose in die Vene fließen zu lassen. Solange die Narkose tief genug ist, infundiert man daher aus einem zweiten Gefäss langsam physiologische Kochsalzlösung; ferner ist es nötig, auch am Schlusse der Narkose die Infusionsvene nochmals mit ca. 100 ccm physiologischer Kochsalzlösung durchzuspülen, damit nicht nach Beendigung der Narkose Aetherlösung in der Infusionsvene stagniert. Zur Verhütung von Thromben gehört weiterhin eine tadellose Asepsis, welche eine selbstverständliche Bedingung bei Ausführung intravenöser Narkosen darstellt. Kleine Thromben, welche sich in wenigen Fällen nach Beendigung der Narkose in der unterbundenen Vene oft bis zur nächsten Teilungsstelle bilden, sind harmlos.

Die bei der Narkose gleichzeitig erfolgende intravenöse Infusion grösserer Mengen physiologischer Kochsalzlösungen stellt teils einen Vorteil, teils einen Nachteil der Methode dar.

Ein Vorteil besteht darin, dass die gleichzeitige Kochsalzinfusion eine belebende Wirkung auf die Gewebe ausübt, dass die Ausscheidung des Narkotikums, sowie das Erwachen prompter und ohne Nachwirkungen erfolgt; auch vermag die infundierte Kochsalzlösung als Ersatz des verloren gegangenen Blutes zu dienen.

Andererseits gibt es Fälle, bei denen die intravenöse Infusion grösserer Flüssigkeitsmengen schädlich wirken kann. Herz und Gefässe müssen widerstandsfähig und elastisch genug sein, um gesteigerten Ansprüchen genügen zu können; denn durch die Kochsalzinfusion wird dem Herzen eine Mehrleistung zugemutet, die allerdings für gesunde oder nicht schwer alterierte Zirkulationsorgane ohne Bedeutung ist. Nach den Ergebnissen experimenteller und klinischer Untersuchungen ändert sich auch bei sehr reichlichen intravenösen Kochsalzinfusionen der in physiologischen Grenzen sich haltende Blutdruck nicht nennenswert, dagegen steigt der pathologisch erniedrigte Blutdruck alsbald zur Norm an, während der schon vorher pathologisch erhöhte Blutdruck häufig eine weitere oft nicht unwesentliche Steigerung erfährt.

Die Schädigung der Respirationsorgane ist bei der intravenösen Aethernarkose eine geringere als bei der Aetherinhalationsnarkose. Bei

dieser sind es vor allem die eingeatmeten kalten Aetherdämpfe, welche die Schleimhäute und Lungen reizen. Bei der intravenösen Methode wird nur der im Körper erwärmte Aether wieder ausgeschieden, sodass Entzündungen der Respirationsorgane infolge der Narkose vermieden werden.

In ihrer Wirkungsweise grundsätzlich verschieden vom Chloroform und Aether verhalten sich die nichtflüchtigen Narkotika. Sie haben fast alle den Nachteil der langsamen Wiederausscheidung aus dem Organismus, was ihre klinische Eignung zu Narkosezwecken schwer beeinträchtigt. Experimentelle Versuche wurden angestellt mit intravenösen Injektionen wässriger Lösungen von Urethan, Hedonal, Chloralhydrat, Isopral, Veronal, Medinal, Chloralamyd, Paraldehyd in verschiedenster Konzentration. Nur Hedonal und Isopral haben auch klinische Anwendung in einer grösseren Zahl von Fällen gefunden; bei allen anderen Mitteln zeigte schon das Tierexperiment, dass sie zu Narkosezwecken beim Menschen ungeeignet sind.

Das *Hedonal* wird grösstenteils als Harnstoff mit dem Harn wieder ausgeschieden. Seine Löslichkeit in Wasser beträgt nur 0,75:100,0. Zur intravenösen Narkose am Menschen wurde Hedonal zuerst von Fedoroff in Petersburg auf Krawkows Vorschlag verwendet, dann auch von zahlreichen anderen, insbesondere russischen Klinikern. Nach eigenen und den in der Literatur niedergelegten Erfahrungen anderer Kliniker lässt sich folgendes über die Hedonal-Narkose sagen: Das Stadium der Toleranz wird nach Infusion von 200–400 ccm der Lösung meist ohne Excitation erreicht, bei $\frac{1}{2}$ stündiger Narkosendauer werden etwa 700–900 ccm der Lösung verbraucht. Die Narkose verläuft in der Regel gleichmässig ruhig und tief. Im Stadium der Toleranz sinkt der Blutdruck um ca. 20 mm Hg. Nach Beendigung der Narkose dauert ein bewusstloser, schlafähnlicher Zustand meist noch mehrere Stunden an. Nach dem Erwachen beobachtete man in mehreren Fällen starke Erregungszustände, die 30–40 Minuten anhielten.

Die Vorteile des Hedonal gegenüber dem Aether bestehen darin, dass das Hedonal die Respirationsorgane ganz unbeeinflusst lässt und, dass die Dosierung des Narkotikums eine genauere ist. Als Nachteile sind zu bezeichnen: Die verzögerte Ausscheidung des Hedonals und die dadurch verursachte erschwerte Dosierbarkeit der Narkose¹ und lange Nachwirkung, welche hypostatische und Fremdkörper-Pneumonien begünstigt; ferner die nicht seltenen Erregungszustände nach dem Erwachen und die Herabsetzung des Blutdruckes während der Narkose.

Bei Ueberdosierung kommt es auch bei Hedonalnarkosen zu einer Lähmung des Atmungszentrums. Asphyxien sind mehrfach beobachtet worden. Das Hedonal ist daher so wenig ungefährlich als der Aether.

Berücksichtigt man, dass die intravenöse Narkose gerade bei den Fällen ihre Indikation findet, bei denen rasches klares Erwachen nach

¹ Es ist zu unterscheiden zwischen der Dosierbarkeit der Narkose und der Dosierbarkeit des Narkotikums.

der Operation und Vermeidung einer Blutdruckerniedrigung während derselben von besonderer Wichtigkeit ist, so muss der intravenösen Aethernarkose vor der intravenösen Hedonalnarkose den Vorzug gegeben werden.

Das *Isopral*, ein der Chloralgruppe zugehöriges Narkotikum verbindet sich im Körper nach Impens mit Glykuronsäure und wird in dieser Verbindung mit dem Harn wieder ausgeschieden. Seine Wasserlöslichkeit beträgt 4 : 100. Zur Narkose beim Menschen eignet sich am besten eine 1,5 Prozent Lösung. Die Auflösung des Isoprals in der sterilen Kochsalzlösung beansprucht bei öfterem Durchschütteln ca. 24 Stunden. Die Lösung hält sich bei steriler Aufbewahrung tage- und wochenlang, Bakterien kommen in ihr nicht zur Entwicklung. Die Lösung muss *langsam infundiert* werden, ca. 40–50 ccm in der Minute. Das Stadium der Toleranz wird erreicht bei ruhiger Atmung und ohne Pulsschwankung nach Infusion von 100–200 ccm der Lösung. Excitation fehlt, auch bei Potatoren und kräftigen Menschen. Im Verlaufe einer $\frac{1}{2}$ stündigen Narkose werden maximal 220–300 ccm der Lösung verbraucht. Der Blutdruck sinkt in tiefer Isopralnarkose um ca. 10–20 mm Hg. Klares Erwachen ohne Kopfschmerz oder Uebelkeit erfolgt 30–40 Minuten nach Beendigung der Infusion. Blut- und Nierenschädigungen wurden nicht beobachtet. Bei Verbrauch grösserer Mengen der Lösung von etwa 300 ccm an traten in einigen Fällen nach dem Erwachen ziemlich starke Erregungszustände ein, die ca. eine halbe Stunde anhielten.

Das Isopral hat vor dem Aether und Hedonal den Vorzug, dass man zur Narkose einer um fast zwei Drittel geringeren Menge der Lösung bedarf, und dass das Toleranzstadium noch prompter und ruhiger erzielt wird. Auch besitzt das Isopral den Nachteil des Hedonals der langen Nachwirkung nicht. Es wirkt aber, wie Hedonal, Blutdruck erniedrigend und verursacht nach grösseren Dosen in einzelnen Fällen Erregungszustände nach dem Erwachen. Zu länger dauernden Narkosen eignet es sich daher der zu grossen Verbrauchsmenge wegen nicht.

Das Isopral ist aber ein sehr brauchbares Mittel zur Einleitung der intravenösen Aethernarkose, an Stelle des Scopomorphins, vor dem es den Vorzug des raschen Erwachens der Patienten nach der Narkose hat. Nach den bisherigen Erfahrungen an etwa 500 Fällen empfiehlt es sich, die Isoprallösung bis zum Eintritt der Toleranz, als Maximum aber 200 ccm langsam zu infundieren. Die Narkose wird dann mittels Infusion der Aetherlösung mit wesentlich geringerem Aetherverbrauche fortgeführt. Bei schwächlichen und kollabierten Patienten und bei sogenannten Halbnarkosen, wird in der Regel kein Isopral injiziert.

In dieser Form genügt die intravenöse Narkose z. Z. am vollkommensten den Anforderungen, welche wir an eine Allgemein-Narkose stellen müssen: Rasches für den Patienten unmerkliches Erreichen des Toleranzstadiums ohne Excitation und ohne Angst oder Erstickungsgefühl; leichteste Dosierbarkeit der Narkose; rasches klares Erwachen nach Beendigung der Narkose ohne Nachwirkungen.

Die bisherigen mit der intravenösen Narkose erzielten Resultate erlauben *folgendes Urtheil* über die Methode :

Die intravenöse Narkose ist relativ ungefährlich, sie verlangt jedoch eine vollkommene Technik, strenge Asepsis und genaue Indikationsstellung. Infolge ihrer grösseren Umständlichkeit und subtileren Technik vermag sie die Inhalationsnarkose nur da zu ersetzen, wo sie wesentliche Vorteile vor dieser bietet. Die mit der Narkose gleichzeitig erfolgende Infusion einer grösseren Flüssigkeitsmenge bedingt Kontraindikationen der Methode. Herzkrankte, Arteriosklerotiker und Patienten mit schweren Kreislaufstörungen eignen sich nicht für die intravenöse Narkose. Vorteile vor der Inhalationsnarkose bietet sie bei den Operationen am Kopf und Hals, bei kachektischen, kollabierten und entbluteten Patienten, bei toxischer Blutdrucksenkung und bei Operationen mit grösserem Blutverlust. In diesen Fällen ist die intravenöse Aethernarkose die geeignetste Methode der Allgemeinnarkose und auch der intravenösen Hedonalnarkose vorzuziehen.

Die intravenöse Narkose kann ferner, falls keine der genannten Kontraindikationen vorliegen, bei jedem Patienten ausgeführt werden, der einen ausgesprochenen Widerwillen gegen die Einatmung des Narkotikums hat. Sie bietet gerade auch in subjektiver Beziehung besondere Vorteile, die im Mangel jeden Beängstigungsgefühles im Beginne der Narkose und in dem raschen klaren Erwachen kurz nach der Narkose ohne Gefühl von Uebelkeit und Kopfschmerz bestehen.

Zur *Ausführung* der Narkose dient ein Apparat an dessen verstellbarem Stativ drei Gefässe, je eines für die Isopral-, die Aether- und physiologische Kochsalzlösung angebracht sind. Die in sterilen Kolben vorrätig gehaltene Isoprallösung wird vor dem Gebrauche steril filtriert und auf 30 Grad erwärmt. Die Mischung der Aetherlösung geschieht erst unmittelbar vor dem Gebrauche und zwar sehr sorgfältig, sodass der Aether in der Flüssigkeit gleichmässig verteilt ist. An den drei Gefässen befinden sich Glashähne und an diesen Gummischläuche, die vermittle eines dreiar- migen Schaltstückes in Verbindung mit einem Regulierhahn stehen, der gestattet in jeder Geschwindigkeit die Lösung ausfliessen zu lassen. An den Regulierhahn ist dann mittels eines kurzen Gummiröhrchens die zur Einführung in die Vene bestimmte Glaskanüle angebracht. Solange aus einem Gefässe die Lösung in die Vene fliesst sind die zu den beiden anderen Gefässen führenden Gummischläuche durch Klemmen verschlossen. Gefässe, Schläuche und Kanülen sind ausgekocht, vor dem Einführen der Kanüle in die Vene muss natürlich alle Luft sorgfältig aus Gefässen und Schläuchen entfernt sein.

SUB-SECTION VII (b)

ANÆSTHESIA, GENERAL AND LOCAL

DISCUSSION No. 2

RECENT METHODS OF GENERAL ANÆSTHESIA

REPORT BY S. J. MELTZER, M.D., LL.D., OF THE ROCKEFELLER
INSTITUTE, NEW YORK

(d) ETHER ANÆSTHESIA BY INTRA-TRACHEAL INSUFF-
FLATION

(With one Figure)

THE subject assigned to me for a report is : Ether anæsthesia by the method of intra-tracheal insufflation. But in order to present the subject intelligibly, it has to be preceded by a discussion of the nature of the new method. Intra-tracheal insufflation consists in blowing air through a tube which has been introduced through the mouth and larynx deep into the trachea. The current of air which leaves the tube just above the bifurcation of the trachea returns between the tube and the tracheal wall and escapes through the mouth and nose. The air current should remain continuous ; but its volume should be reduced for a second or two several times a minute. The air can be driven by various contrivances, which, however, need not be discussed here. Previous to its entering into the intra-tracheal tube, the air may pass through a bottle containing ether and thus carry ether vapour to the lungs, and by a very simple construction it is arranged that either pure ether vapour or pure air may be carried to the lungs, or a mixture of the two in any desirable combination.

The following considerations will assist in elucidating the principle underlying this method and its advantages for the function of respiration. The actual process of the external respiration, that is, the exchange of gases, occurs in the air-cells ; oxygen is absorbed from the air-cells into the blood of the lung capillaries, and carbon dioxide is eliminated from the capillaries into the cells. If the air-cells or the alveoli would open without intervention on the surface of the body and thus be in immediate communication with the pure air, no respiratory movements would be necessary. As it is, the air-cells are in communication with the pure air only by means of a long air-shaft consisting of the bronchi, trachea, larynx, pharynx, and mouth and nose. The pure air can be brought there only by means of a pumping-machine, the complicated respiratory

mechanism. That long shaft is termed *dead space*. The air-cells are like mines deep under the surface of the earth. In order to maintain life there, pure air must be pumped into and bad air sucked out through a long shaft by means of powerful machinery. It is evident that the nearer the mine is to the surface, and the shorter the shaft is which has to connect the mine with pure air, the less need there is for a pumping machinery. In the method of the intra-tracheal insufflation pure air is brought down to the bifurcation of the trachea, whereby the greatest part of the intervening dead space is cut out. Furthermore, the air is brought down to the very mouth of the bronchi with a certain force, which favours an accelerated and powerful diffusion of the gases within the bronchi. In experiments made on animals in which the tube was inserted through an incision in the trachea, and in which the relation of the diameter of the tube to the lumen of the trachea could be properly selected, we found indeed that we may abolish the respiratory movements completely by means of curare, without impairing in the slightest the other functions of life. However, in introducing the tube through the mouth and larynx it is impossible to select each time a tube of a diameter best adapted for each individual case. But here we found that by very brief and infrequent variations of the continuous air current we were again able to support the life of completely paralysed animals in a most satisfactory manner. In short, the principle of the effectiveness of the method of the intra-tracheal insufflation is based upon its cutting down the greatest part of the dead space in the respiratory mechanism. I may add that, in my opinion, in this method the function of respiration is provided with more *factors of safety* than in the normal respiratory mechanism.

I wish to point out another feature which differentiates it from the normal respiration and which is of considerable practical importance. In the normal respiration it is only during the act of expiration that the direction of the air current is from the lungs to the surrounding atmosphere. During the inspiration the air is driven or rather sucked from the mouth, nose, pharynx, larynx, and trachea into the lungs. This inspiratory air current is capable of carrying blood and infectious matter into the lungs. Under normal conditions there are various defensive factors which attempt to prevent such undesirable invasion. However, in a state of helplessness unconsciousness, or anæsthesia, these factors are inefficient. Hence the fear of aspiration pneumonia under anæsthesia. It is different, however, with our method. During the entire period of intra-tracheal insufflation there is a continuous air current blowing forcefully from the trachea and larynx through pharynx, mouth, and nose. By extensive experiments we proved the protective efficiency of this recurrent air stream. In one series of experiments the pharynx was filled with charcoal while the animals remained for hours under deep ether anæsthesia by continuous intra-tracheal insufflation. Not a speck of charcoal found access into the trachea. In other experiments animals were made to vomit by means of apomorphin, while the pharynx remained uncleaned for an hour or

two, and again nothing of the vomitus entered the pharynx and the trachea. In some cases the vomitus was made very acid ; the reaction of the mucous membrane of the trachea remained nevertheless alkaline. I need not tell you what such a protection means for surgery on the mouth and pharynx.

Our subject is anæsthesia. But I may mention in passing that under intra-tracheal insufflation the entire thorax may be split transversely, the lungs completely lifted out from the chest, the vagus nerves cut or carelessly handled ; or diverse operations performed on the heart, the large blood-vessels, lungs, or œsophagus without impairing in the least the efficiency of the function of respiration. Under this method of respiration life can be readily maintained for many hours while the thorax remains wide open on both sides. Cotton and Boothby kept a cat anæsthetized sixteen hours by nitrous oxide and oxygen administered by the intra-tracheal method with both pleural cavities widely opened ; on the discontinuation of the anæsthetic the animal recovered within fifteen minutes.

The conception generally prevails that the mucous membrane of the trachea is delicate and sensitive ; on presenting my first communication a few years ago, the fear was expressed that the presence of a catheter in the trachea for many hours would necessarily lead to inflammation and infection of the respiratory organs. In the intervening years I employed the method in several hundreds of animals ; in many cases autopsies were made soon after the experiments, or days and weeks later ; in some instances the intra-tracheal insufflation was employed continuously for twenty-four hours. These experiments have shown conclusively that these fears were unfounded ; no laryngitis, tracheitis, bronchitis, or pneumonia followed these experiments. Furthermore, the method of intra-tracheal insufflation has now been tried on human subjects in more than fifteen hundred operations. I shall return to this fact latter. At present I wish only to emphasize the fact that the experiences of the various surgeons harmonize completely with my experimental results. We may, therefore, conclude that the mucous membrane of the trachea is not more sensitive than many other mucous membranes, and that on the score of sensitiveness of the trachea there should be as little objection to the method of intra-tracheal insufflation as there is, for instance, to the introduction of a catheter into the urethra.

To recapitulate the essential points briefly : Intra-tracheal insufflation is a safe method for artificial respiration, it eliminates the largest part of the dead space, it prevents aspiration and infection by the recurrent air stream, and is capable of keeping up the respiration most satisfactorily even in completely paralysed animals as well as in animals with widely opened pleural cavities.

I now come to the use of the method of intra-tracheal insufflation for ether anæsthesia. Before its entrance into the intra-tracheal tube, the air current may be sent, wholly or partly, through the upper part of a bottle which is partly filled with ether. Ether vapour is then taken

up by the air current and driven through the intra-tracheal tube, with a certain force, to the lowest part of the trachea and continuously returned with the same degree of force through the space between the tube and the tracheal wall, escaping finally through the mouth and nose into the air. The ether vapour thus courses continuously from the bottle to the air outside of the mouth through a channel which has an opening near the bifurcation. Through this opening a fraction of the ether current escapes and reaches the respiratory surface and the circulation, into which it enters and produces anæsthesia. This effective fraction of ether has only a short way to traverse from the inner end of the tube to the air-cells. The method has also the advantage that the ether on its way to the circulation does not have to come in contact with the sensitive areas of the respiratory tract innervated by the trigeminus and superior laryngeal nerves, a contact which in the ordinary method of anæsthesia frequently annoyingly complicates its course. Several years ago I recommended the use of the method of intra-tracheal insufflation for the administration of ether anæsthesia; the recommendation was based on laboratory experience in a series of experiments on dogs. I at that time stated that in these experiments I could not kill the animals by ether when administered by this method, although the anæsthesia was readily attainable and perfect. In the numerous experiments which we have carried out in the intervening years, we learned how to kill the animals by ether even with this method, but we learned to know the circumstances surrounding these deaths, we learned to recognize early these dangers, and we learned how to avoid them safely. Besides the laboratory experiments of our own and those of others, there exists already quite a large record of observations made in surgical operations upon human beings by very able and critical surgeons. It is a gratifying fact that the verdict of these surgeons is unanimously favourable to the use of the method of intra-tracheal insufflation for anæsthesia. Dr. Elsberg, of the Mount Sinai Hospital of New York, who was the first to introduce the method in human surgery, and whose personal experience extends over a thousand cases, will speak, I hope, for himself. Dr. Peck, of the Roosevelt Hospital in New York, who reported in May 1912 his observations on 216 cases, says: 'We have found the method absolutely safe and have seen no harmful results of any consequence.' Dr. Samuel Robinson, who in a paper before the Massachusetts Medical Society analysed the results of 1,400 cases of intra-tracheal ether anæsthesia from fifteen surgical clinics, comes to the conclusion 'that intra-tracheal anæsthesia is as safe a method of ether anæsthesia as we have at our disposal, regardless of the seat of the operation'. He says further: 'Those of us who have managed intra-tracheal anæsthesia during general surgical operations are universally impressed with the ideal conditions which exist. The patient appears to be under a hypnotic rather than an anæsthetic.' Professor Frazier of the University of Pennsylvania writes: 'I am prepared to testify as to the safety of the procedure. I have had absolutely nothing in my

experience to give the least cause of anxiety, and I believe the method is the safest I have seen for the administration of ether.' As to my own experience, I shall say in the first place that in many hundreds of experiments on dogs I have not met with a single instance of a pathological condition of the trachea, bronchi, or lungs of any consequence which could have been ascribed to the ether or to the intra-tracheal insufflation. In many instances the ether insufflation lasted uninterruptedly from fourteen to twenty-four hours; the autopsies have shown that the respiratory tracts remained perfectly normal. Moreover, in a number of dogs, Githens and I produced lobar pneumonia by the method of intra-bronchial insufflation, and then insufflated ether for one hour every day for ten days without any harmful interference with the favourable course and outcome of these cases. In human surgery it is interesting to note that surgeons with extensive experience observed practically no post-operative effects on the respiratory tract. Peck says in his published paper that there was no post-operative pneumonia in his 216 cases, while during the same period he had five ether pneumonias in cases in which other methods of anæsthesia were used. In a private communication kindly made to me, Dr. Peck reports that in a new series of seventy cases, one case of ether pneumonia occurred in a patient to whom anæsthesia by the ordinary method was administered for half an hour previous to the introduction of the tube into the trachea by an inexperienced man. The least that can be said of the method is that it gives no more rise to post-operative ether pneumonia than any other method of anæsthesia. But there is good reason for the hopeful expectation that with a good technique and intelligent management of the method of intra-tracheal insufflation post-operative pneumonias will be greatly reduced. The continuous recurrent air stream of this method is certainly a protective factor against aspiration pneumonia.

From the studies by Githens and myself of the toxic effect of ether when administered by the intra-tracheal insufflation method, the following results are of considerable importance. When the administered amount of ether exceeds the dose required for complete anæsthesia, the respiration becomes shallow, and, if persisted with the same dose, the respiration disappears completely and a little later the blood-pressure begins to fall. The descent of the blood-pressure is, however, slow and gradual, so that two hours may pass after the cessation of the spontaneous respiration before the blood-pressure reaches a dangerously low level. At this stage the pulse-pressure, which remained practically unchanged, becomes rapidly smaller. The animal is then in immediate danger. But when now the ether is reduced, or entirely eliminated, the pulse begins to improve within a few seconds, the blood-pressure starts an ascending course, and the animal is out of danger again. The respiration returns some time later, and, if the ether is turned off entirely, consciousness sets in after fifteen to twenty minutes. The meaning of these phenomena is this. When the administered quantity of ether

exceeds the anæsthetic dose it becomes toxic for the centres of the medulla. Deglutition disappears first and the centre of respiration succumbs soon after. The vaso-motor centre, however, becomes affected very slowly, and the last to succumb to the ether intoxication are the heart and the peripheral mechanism of the blood-vessels. The disappearance of the spontaneous respiration offers as such no danger whatsoever, the needs of that function are being well taken care of by the intra-tracheal insufflation; but the cessation of the spontaneous respiration is here a clear sign that the centres of the medulla oblongata are beginning to become intoxicated by the ether. It is a danger signal; but fortunately it is given very early, and the remedy is promptly at hand: a slight turn of the stop-cock and the etherization is transferred from the toxic to the safe anæsthetic zone again. In intra-tracheal insufflation the state of the spontaneous respiration is the best indicator of the safety of the anæsthesia, and anæsthetists and surgeons should not welcome a state of apnoea, when it occurs during etherization.

As far as I am aware, as yet no accidents have happened in the use of the insufflation method in human surgery which could be ascribed to the use of an excess of ether. The criticism goes rather in the opposite direction, namely, that in some instances the patients, especially alcoholics, cannot be kept under complete anæsthesia. On the basis of our experiments we believe that this can be easily remedied. In the first place, the bottle which contains the ether should have a large diameter. Githens and I have established by experiments that the effectiveness of the etherization is proportional to the diameter of the ether bottle, the larger the diameter, the sooner the anæsthesia develops and the deeper it becomes. Most of the apparatus, for the sake of compactness, contain rather small bottles. We found, further, that the smaller the empty space in the bottle above the ether is, the more prompt is the anæsthesia. An animal often may come out of the anæsthesia merely by the increase of the space above the ether, although the bottle contains still a good deal of it. The most important factor, however, is the size of the tube in relation to the lumen of the trachea. The larger the diameter of the tube, the smaller, of course, is the space between the tube and the tracheal wall, and the volume of ether, which is driven in through a wider tube, finds diminished facilities for returning; the result is, therefore, a more rapid and deeper anæsthesia. With wide tubes one sees a very early cessation of the respiration after only a small quantity of ether has been used up. Too large a tube is dangerous, even when the apparatus is provided with a safety-valve, on account of the restriction in the elimination of the carbon dioxide. I therefore advise to make the error rather in the direction of using too small tubes. The tubes which have been used originally for adults were catheters No. 22 French. From hospitals with few alcoholics we do not hear of failures with this tube. However in hospitals which have to receive many alcoholic patients the result seemed to have been often less satisfactory. My advice is that for an

alcoholic patient a 24 French catheter should be used, while for other normal patients the use of a 23 French catheter may be the rule. These diameters are surely not too large for adults, and I believe that anæsthesia by these larger tubes will be found to be more satisfactory in many respects—unless they prove to be too large for some particular individual. As a rule I believe that a 24 French catheter will never be found too large for adults. But anæsthetists should learn to know the symptoms which too large tubes produce. The spontaneous respiration becomes very soon too slow, and the expiration is prolonged, active, and laboured. The respiration may even cease completely a few minutes after the beginning of the insufflation, while only a small quantity of ether has been consumed. There need not yet be any cyanosis, and the anæsthetist had better not wait for its appearance. There is no other remedy against too large a tube except its withdrawal and the substitution of the next smaller size.

There is, however, a reliable and simple remedy when the tube is found to be too small. A light pressure with one finger over the hyoid bone, just above the thyroid cartilages, for a few seconds, four to five times in a minute, will bring on in a short time the desired deep anæsthesia. It should not be pressed anteriorly to the hyoid bone, because that may be the means of driving air into the stomach. *I must strongly advise against the method of having air bubble through the ether itself*, which some surgeons advocate for the purpose of accelerating the anæsthesia. This method was apparently the cause of death in one instance. By some error pure ether, instead of its vapour, was driven into the lungs. The best precaution against the dangers of this method is not to use it.

I must also strongly urge that every kind of apparatus which may be used for intra-tracheal insufflation should be provided with a safety-valve which is capable of controlling the maximum pressure under which the air may enter into the intra-tracheal tube. The construction of such a safety-valve is very simple. The open end of the perpendicular branch of a T-tube which is interpolated somewhere between the blowing apparatus and the intra-tracheal tube is made to dip 15 or 20 mm. deep under the surface of mercury. Any excess of the pre-arranged pressure will cause the air to bubble through the mercury, and will thus never reach the lungs. The few cases of emphysema, with and without fatal outcome, which have occurred as a result of the use of the intra-tracheal insufflation, could have been safely prevented by the presence of a safety-valve in the apparatus. The safety-valve may be set in every instance for not less than 20 mm., and when the intra-tracheal tube proves to be too small even a pressure of 25 or 30 mm. is not too high. Githens and I have established by experiments that the pressure in the trachea and in the bronchi is only a small fraction of the pressure in the manometer outside of the body, and that the intra-tracheal pressure grows considerably less with the decrease of the diameter of the intra-tracheal tube.

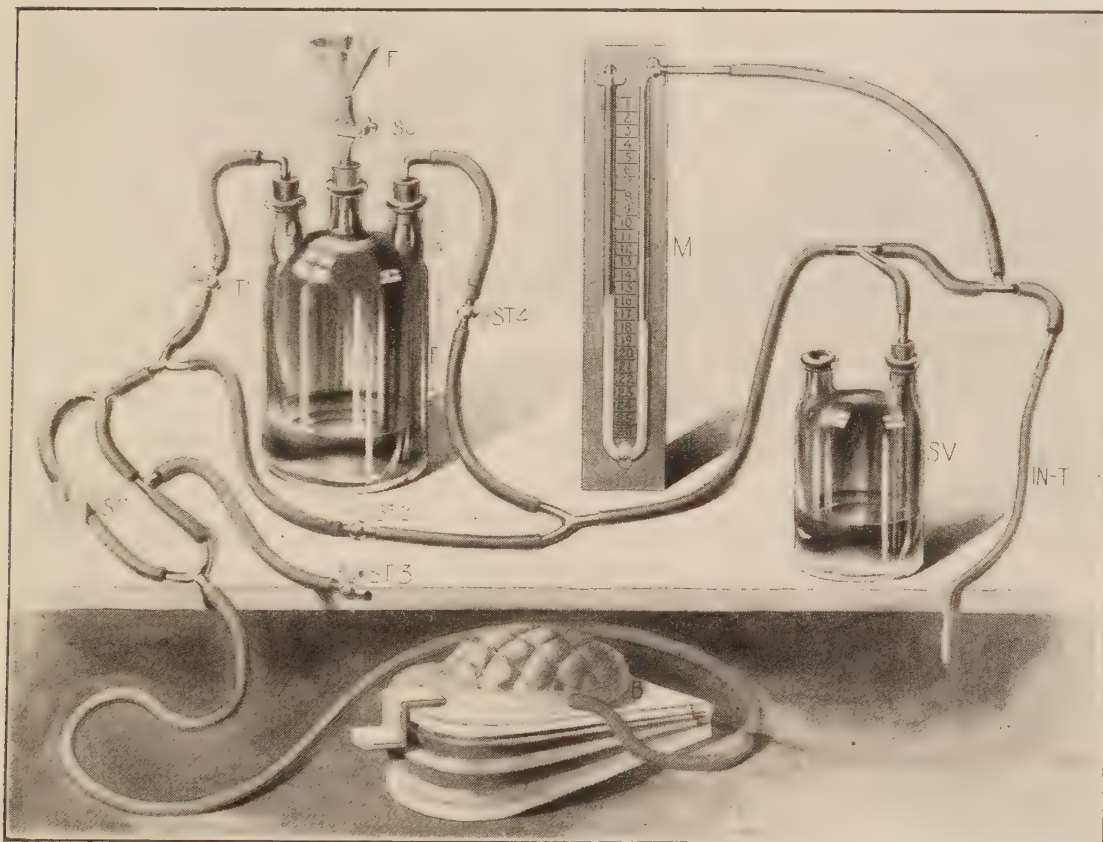
Anæsthetists and surgeons must keep in mind that any careless pressure

upon the trachea may prevent the return of the insufflated air and lead to disaster. It may seem that such a warning is unnecessary. But the literature contains the report of a case in which the head of the patient, who was in the prone position, was strongly flexed over the end of the table with long narrow sand-bags under the neck. Although it was 'early observed that the air was not passing through the ether with the usual freedom' the operation was continued without making any change in the position of the patient. An extensive subcutaneous emphysema developed, from which the patient, however, recovered. Evidently the external pressure on the trachea prevented the return of the insufflated air, thus increasing unavoidably the intra-alveolar pressure, which led to the breaking of the pulmonary tissue and to the escape of air into the loose tissue around the bronchi and trachea and from here to the adjacent subcutaneous tissues. Had there been a safety-valve in the apparatus employed no such breaking of the lung tissue would have occurred; but the patient might have had to succumb finally to the asphyxia resulting from the restricted return of the carbon dioxide. I subscribe to the statement of Peck that the method 'is not fool proof and certain cardinal principles must be thoroughly understood and carefully guarded in its administration'.

I append here the sketch of an apparatus which fulfils in a very satisfactory manner all the requirements of the method. At the same time it is inexpensive and can be easily put together without the aid of a mechanic.

By means of a glass-blower's foot-bellows (B) air is driven at will through a system of branching tubes into the intra-tracheal tube (IN.-T.). The first branching of the tubes is introduced for the purpose of regulating the interruption of the air stream. From the right branch a tube is led off laterally, carrying a stop-cock (ST. 3), which is to be used for the interruptions of the air current. During the opening of the stop-cock a part of the air current continues through the left tube, thus preventing too great a reduction of the pressure, which is undesirable. By means of a screw clamp (s. c.) the amount of air which is to pass through the left tube can be regulated; a narrowing of this tube causes a greater collapse of the lungs during the interruption. The second branching of the tubes is introduced for the purpose of regulating the anæsthesia. The ether bottle (E.) is interpolated in the left branch; the right branch runs uninterrupted outside of the bottle to unite with the part of the left tube which comes from the ether bottle. When the stop-cock in the right branch (ST. 2) is closed, all the air passes through the ether bottle; when both stop-cocks in the left branch (ST. 1 and 4) are closed, only pure air reaches the intra-tracheal tube, and when all three stop-cocks are open, only one-half of the air is saturated with the anæsthetic. By partial closing of the stop-cocks various degrees of anæsthesia can be obtained. The third opening in the ether bottle carries a tube with a funnel (F.) through which the bottle is filled with the anæsthetic; the tube is otherwise kept tightly closed by means of a screw clamp (s. c.). All three rubber stoppers are firmly and permanently wired down to resist various pressures. When the ether bottle is to be refilled during insufflation, both stop-cocks on the left side are closed, while the one on the right side is open.

The tube which connects the anæsthesia circle of tubing with the intra-tracheal tube (IN.-T.) carries two lateral tubes; one is connected with a manometer (M.), which needs no description, and the other leads to a safety-valve (S. V.) of simple construction. To the rubber tubing is attached a calibrated glass tube, the lower end of which is immersed under the surface of the mercury in the bottle to a depth corresponding to the pressure which is desired for the intra-tracheal insufflation. For instance, if the pressure should be not more than 20 mm. of mercury, the glass tube is immersed just 20 mm. below the surface of the mercury. The glass tube is kept in the desired place by means of a rubber ring resting upon the opening of the mercury bottle. This device gives great safety to the working of the method. No matter how strong and irregular the bellows



A simple apparatus for ether anæsthesia by intra-tracheal insufflation.

is worked, the intra-tracheal pressure could never rise above the one arranged for; the surplus of air escapes through the tube from under the mercury.

In this arrangement a wash bottle can be inserted containing warm Ringer's solution, which would serve as a filter as well as a source for heat and moisture. In our experimental work we never used it and never missed it.

In our laboratory the air is supplied by a pump which is driven by electric power, and the interruptions are made automatically by a mechanical contrivance. This machine carries air to several operating-tables, which enables us to use the method of intra-tracheal insufflation in several experiments simultaneously. The above-sketched apparatus was devised by me originally for the thoracic experiments of Alexis Carrel. I reproduce it here chiefly for the purpose of bringing out the few features which

I deem indispensable for the efficiency of any apparatus. In order of their importance, *I mention in the first place the SAFETY-VALVE (S. V.)*. No apparatus should be without it. Next in importance is a device for interruptions (ST. 3). In cases of inefficient respiration from whatever cause the interruptions are indispensable. A side branch for the maintenance of some degree of continuous respiration should not be missing. *Especially in operations upon the thorax the lungs should never collapse completely*. The degree of the collapse should be regulated by the screw clamp (S.C.). A greater compression of the left side branch might sometimes prove to be the means of abolition of a cyanosis. The tubes entering and leaving the ether bottle should be remote from the ether surface. However, the bottle should be at least two-thirds full of ether, and, to mention again, it should be of a large diameter. In addition I wish to emphasize again that *the tube should not be introduced with too much energy*; that with regard to the diameter of the tube it is safer to err rather in the direction of using too small than too large a tube; that anæsthetists and operators should avoid undue pressure upon the neck; and finally that *with the appearance of so-called apnœa the ether should be turned off*.

SUB-SECTION VII (b)
ANÆSTHESIA, GENERAL AND LOCAL
DISCUSSION No. 2

RECENT METHODS OF GENERAL ANÆSTHESIA

REPORT BY DUDLEY W. BUXTON, M.D., B.S., M.R.C.P., PRESIDENT
OF THE SUB-SECTION OF ANÆSTHESIA ; CONSULTING ANÆSTHETIST
TO THE NATIONAL HOSPITAL FOR THE PARALYSED ; ANÆSTHETIST
AND LECTURER ON ANÆSTHETICS IN UNIVERSITY COLLEGE
HOSPITAL AND MEDICAL SCHOOL.

(h) THE DOSIMETRIC METHOD OF ADMINISTERING
CHLOROFORM

THE principles involved in this method are :

(i) Chloroform acts upon the tissues of the human body directly in proportion to the strength of its vapour contained in mixtures with air or other gases, or if it is in solution, in direct proportion to the strength of its vapour as given off by the chloroform and other liquids in which it is in solution, e.g. ether, alcohol, oil.

(ii) Its action is progressive in the sense that while the dilution remains constant, when administered for a prolonged period the resulting narcosis becomes deeper and deeper.

(iii) Its action is different in degree although similar in character when affecting different tissues of the body. Thus low percentages of its vapour, e.g. below 1 per cent., do not produce anæsthesia but lower body temperature and interfere with metabolism. Higher percentages, e.g. 2 per cent., induce anæsthesia, and if given for a prolonged period progressively lower blood-pressure, and prejudice the function of respiration.

(iv) Ultimately chloroform acts as a protoplasm poison, first lessening function, finally destroying the power of functioning. Such effects vary directly as the strength of the chloroform vapour which enters the organism.

(v) There is no reason to believe that the action of chloroform is capricious, but there is every evidence to show that it reacts more vigorously towards tissues which are abnormal, the pathological condition arising as the result of interference with the normal processes of life, e.g. the onset of asphyxia ; or as the result of pathological conditions affecting the tissues of the organism, e.g. the blood, the organs or congenies of organs or tissues, e.g. anæmia ; diseases affecting respiration

or circulation ; fatty or degenerative changes in tissue cells, themselves the result of disease and producing a lessening in ability to perform a vital function.

(vi) There is a definite strength of vapour, i.e. a definite percentage, which will in all cases induce anæsthesia, while when this is transcended deeper narcosis results which involves detrimental interference with the functions necessary for life, i.e. circulation, respiration, and metabolism.

(vii) There is further a definite strength or percentage value of chloroform vapour which, when anæsthesia has been completely induced, will maintain anæsthesia without increasing the depth of narcosis. This percentage vapour varies inversely as the length of time during which the vapour is inhaled, being highest at the moment that full induction has been attained and gradually lessening in value until the end of the inhalation.

(viii) Both the values of the percentages requisite for the induction of anæsthesia and those needed for its maintenance while possessing a maximum for the normal adult of average physique are lower for individuals of impaired vitality and for children. This is more especially true of the values of the percentages requisite for maintaining anæsthesia when once produced.

The evidence that chloroform action is uniform and depends upon the strength of the vapour introduced is, that intact animals (Snow, Bert, Dubois, Clover, Lister, Waller) when inhaling vapours between 1 and 2 per cent. become completely anæsthetic. In the case of small animals Snow found that percentages of 1.7 and 2.9 interfered with respiration. His experiments allowed the periods of induction and maintenance to overlap, so that the lower percentage is probably in many instances the one which proved lethal through prolonged inhalation, i.e. maintenance. Further, his animals breathed in a restricted space, itself introducing other factors. Bert arrived at similar results. His maximum of safety was 2 per cent., and danger was constant when this was exceeded. In human subjects, Bert habitually employed 1.6 per cent., and Dubois's experience coincided. In Bert's practice the patient respired from large gas-holders, while Dubois employed a plenum system anæsthetizing machine, which materially increases the amount of the mixture entering the lungs, the dilute vapour being delivered under pressure.

The actual processes operative in bringing about anæsthesia, abeyance of function, and ultimately death, are known to some extent, and our knowledge depends again upon the work firstly of Snow and Bert, while later of McWilliam, Waller, the Hyderabad Commissioners, Professor Wood, Hare, Gaskell, Shore, the Special Chloroform Committee of the British Medical Association, especially the researches of Sherrington and Sowton, Brodie, Harcourt, Horsley ; also of Professor Benjamin Moore and Dr. Roaf, M. Tissot, Dr. Buckmaster, and Mr. Gardner. The extent

to which chloroform passes from the pulmonary air to the blood-stream it is at present impossible to gauge. Its passage appears in the main to be one controlled by the physical laws which govern the passage of gases through a membrane into a fluid, the gas-tension of which is below that of the gas in the space beyond the membrane. The red cells of the blood acting as carriers convey the chloroform to the cells of the tissues and (Moore and Roaf) these aggregate the anæsthetic, with the result that bio-chemical function is at first lessened and ultimately ceases. Both by examination of inspired and expired air and of tissues and blood acted on by chloroform, we learn that the degree of interference with function is directly proportional to the percentage-strength of the chloroform introduced, although we do not know precisely what the percentage in the tissue cells may be. Passing to gross tissues, Waller, in a series of most beautiful experiments, has shown that nerve becomes paresed, and later loses its conductivity, when exposed to a vapour of chloroform progressively increased in strength. A uniform result followed a known percentage-strength of vapour, so that given precisely similar conditions in the case of nerve we can predict that any given percentage-value of chloroform will produce a definite effect on nerve. The amount of hæmolysis following chloroform inhalation is difficult to estimate, as many factors of unknown influence exist in the case of human beings. In dogs this effect is slight (Buxton), greater when large amounts of chloroform are used. The experiments done *in vitro* are of little value. The outcome of a very large amount of work done upon the influence of chloroform upon the heart and circulation appears to be: blood-pressure falls, the heart's action weakens, possibly in part due to dilatation (McWilliam), and the vasomotor control lessens directly as the percentage of chloroform which is in action. Although always tending in the direction indicated, these effects can be controlled while anæsthesia is persistent, provided the percentage of chloroform given is lessened *pari passu* with the length of time during which the tissues are being subjected to the influence of the drug, and that environing conditions remain constant. The onset of asphyxial states, the occurrence of hæmorrhage or traumatic shock profoundly influence the effects. The introduction of oxygen exerts a restraining limitation, while its exclusion accelerates the chloroform effects upon the tissues. Further, normal blood protects tissues, while abnormal, whether through deficiency of constituent parts or owing to its containing some foreign and pathological constituents, renders tissues more vulnerable to the deleterious influence of chloroform. A percentage of chloroform which entering normal blood will induce safe anæsthesia in one patient, may bring about dangerous effects in another, if the state of his blood is vitiated by disease and especially by anoxæmia.

Lastly, authorities, while differing slightly as to what height of percentage is the limit of safety, agree that double the anæsthetic dose of chloroform constitutes the lethal one.

Another point of importance, which has now been fully proved by

the workers named above, is that chloroform affects tissues in the following order :

Nerve-tissues—the more highly differentiated being affected first,
then heart muscle,
later striped voluntary muscle,
subsequently involuntary muscular fibre,

i.e. a low percentage will paralyze nerve-tissue and myocardial fibres, while a far higher percentage is necessary to produce any effect upon voluntary or involuntary muscular fibres. In this fact lies the essence of anæsthesia, if it were not so the practice of producing unconsciousness by inhaling chloroform would be impossible. But as has been formulated above, this progressive effect of chloroform as regards various tissues is also progressive as regards various associated congeries of tissues concerned in carrying on the processes of life. There is no break in procession of events when chloroform enters the organism. One portion of the brain, the most highly differentiated, is thrown out of function when a certain percentage of chloroform is inhaled, and the tissues less sensitive reveal less effect ; later, if the same percentage being inhaled the lower ganglia of the brain come under its influence and blood-pressure falls while pulmonary ventilation suffers diminution and respiratory excursions grow more and more limited. Ultimately the nervous system becomes so much narcotized that it loses all power of function. At such an epoch the tissue life of voluntary and involuntary muscular fibre remains undestroyed. In the case of the tissue of the myocardium chloroform acts rapidly and early, for weighty evidence exists lending support to the view that the heart-muscle soon loses its power of contracting and suffers acute dilatation.

Further, as regards the effect of chloroform upon the central nervous system, we are compelled to believe that some of its normal reflex mechanisms are affected, the effect being proportional to the strength of the chloroform vapour inhaled, in such a way that abnormally severe inhibitions are elicited, due to a hyperæsthetic state of the reflex centre. Embley has shown that with certain percentages of chloroform the vagal centres evince this increased activity, and that the effect of reflex inhibition under these conditions is to cause a heart standstill without the normal power for the organ to escape from inhibition. Yet a further example furnished by Bert's classical experiments shows the effects produced upon metabolism by chloroform. Dogs which were never rendered unconscious were found to die as a result of abeyance of the functions of metabolism.

It would then appear that even if we leave out of the question the massive effects—protoplasm destruction—produced by admittedly toxic percentages of chloroform, there is a very strong case in favour of believing that this anæsthetic produces effects which are directly determined both in their severity and the area over which they extend by

the actual vapour strength which is introduced rather than by the actual amount of the drug which persists in the organism. I may be allowed, however, to indicate parenthetically that this storage of chloroform in the tissues is material to our present theme, although not so evidently so, since it determines the severity and possibly the nature of the sequelæ to chloroform inhalation. It may, and often does, produce a toxæmia, the prominent symptoms of which are tissue changes and tissue destruction; since the essence of a dosimetric system of administering chloroform consists not only in limiting the strength of vapour inhaled—first to induce anæsthesia, secondly to meet the actual requirements of the patient at every epoch of the operation, when environing circumstances challenge the necessity for change of dosage—but also in limiting the strength of vapour as the tissues become more and more under the influence of the drug in order to ensure the effect being one of a merely anæsthetic nature and not of the type of a toxæmia.

It may be said, and with some justice, that all drug action is a toxæmia, but I am using the term rather in the sense of a state brought about by destructive action upon the tissues by a drug, the symptoms of which state persist days or weeks after the elimination of the drug has been effected. Some workers have stated, relying upon experiments, that every person who takes chloroform is mildly poisoned, but may recover. This, so far as it is true, supports dosimetry in chloroform; as to its truth, that depends upon the careful scrutiny of the doses and methods employed in the experiments, a scrutiny which often reveals excess of vapour strength and viciousness of method involving extraneous factors, e.g. asphyxia, starvation, and so on.

Returning to the practical side of our question, it is convenient to consider the phenomena of the periods of (1) Induction, (2) Maintenance, (3) Recovery, including post-operation effects.

Induction. Clinical experience supports the experimental results of Sherrington, Sowton, and others, that whereas the organism can be 'taught' to tolerate even relatively high-percentage vapours if the strength is gradually reached, yet a sudden use at the commencement of an inhalation of such a strength results in collapse and probably death. When we are working out the physiological action of a new drug we use the utmost care to measure the strength employed. When our results are standardized we employ such and such a strength per kilo of body-weight and know that we shall in every case ensure a certain result which we anticipate. In the case of chloroform we have now standardized for the normal person that a strength of vapour somewhere about 2 per cent. will induce anæsthesia, that less will only cause sleep, while a greater strength will always lessen the activities of respiration and circulation and may at any moment cause cessation of breathing and heart standstill. And yet in spite of this knowledge the methods most generally employed provide no means by which the administrator can even know the strength of vapour—i.e. the dose per kilo—he is

giving, while he possesses no accurate control over the unmeasured and unmeasurable quantities of the drug employed. He is for ever experimenting upon his patients, and the results he obtains depend wholly upon his personal acumen as an experimenter. That he must frequently fail is foreordained since in the problem which he seeks to unravel are factors of which he can possess no full knowledge. He depends solely upon his powers of observation, if the results consequent upon his unknown doses seem to be trenching upon the zone of danger he limits his supply of chloroform, but by how much he does not accurately know. Acquainted with the gross pathological changes obvious in his patient and the usual degree of trauma incident to any given type of operation, he nevertheless cannot gauge the more subtle tissue changes which make for resistive power to the 'insult to tissue', or even to the strength of vapour which he is using, while he must always fail to anticipate the contingencies of shock and actual 'insult to tissue' liable to occur in certain cases of difficulty. That many men can intuitively stumble upon a safe dose when employing undosimetric methods is obvious, and that experience will enable such to anticipate events is undoubtedly true, just as the pharmacist may guess his dose of strychnine or other potent drug; but the system lacks the imprimatur of science and is apt to fail at critical moments.

Maintenance. These considerations bear equally upon the periods of induction and maintenance, but as regards the latter, another and equally important one arises. The patient who is safely anæsthetized and kept drugged throughout a prolonged operation may be, and often is, seriously prejudiced as to his recovery when an over-large amount of chloroform has been inhaled by him, even though his life has never been in obvious jeopardy during the administration. He is put into a state of chloroform toxæmia which directly interferes with his chances of safety and of achieving recuperation. With dosimetry, if accurate, he will have received the minimal quantity of the drug; at no time will his organism have been unduly depressed, and at the close of the anæsthesia consciousness will at once return and elimination will be practically finished. This aspect of the case is not sufficiently realized, nor is its importance recognized.

What, then, are the methods at our disposal to obtain dosimetry, and are we assured, on the one hand, that they are reliable, while, on the other, that in removing one set of dangers they do not introduce others?

Those in favour of dosimetry have sought to promote its ends by (1) an open method, with an elaborate system of dropping chloroform upon an absorbing and evaporating surface; (2) by mixtures; (3) by instruments which either present atmospheres of known strengths contained in receivers, or by inhalers so constructed as to determine a more or less accurate commixture of chloroform vapour and air, the strength of which is at all times known to the administrator, and can be varied by him with the utmost accuracy.

In order to test these methods we need to establish certain criteria. These are, first, is there a maximum of dose common to all individuals beyond which a danger zone exists? There have been, and possibly still are, persons who consider that every patient is a law unto himself as regards chloroform, and this can only be decided by testing him; hence they desire as pliant a system of administration as is possible. I think, however, that the evidence is all against such a view, and so it must be abandoned if any scientific concept of the administration of chloroform is to be adopted.

The actual maximum of the percentage of chloroform vapour consistent with safety has been experimentally fixed at 2 per cent. for induction, but some authorities regard this as too low for the requirements of the type of operations usual at the present time. It is not strictly within the purview of my subject to discuss this point, since whatever dosimetric apparatus is in use it can be graded to the required limits. It seems, however, practically proved that the 2 per cent. limit arrived at by Snow, Bert, Dubois, Waller, and recently by the Special Chloroform Committee of the British Medical Association¹, is practically correct for all cases. When this limit is exceeded to obtain a more profound narcosis, it always carries the patient into the danger zone, being associated with a perilous fall of blood-pressure and depression of the respiratory and heart centres.

Snow, Clover, the late Lord Lister, Waller, Levy, and others have shown conclusively that a drop-method can be arranged which gives approximately a definite strength at the outset of the administration, but this is obtainable only by the utmost skill and experience, and only when such disturbing factors as the patient's irregularity of breathing, i. e. variations in depth and rhythm, room temperature, limitation of the 'spread' over the evaporating surface, and prevention of air-currents can be eliminated. Such an arrangement possible under experimental conditions is not attainable in everyday practice. Besides this fact the method is open to the danger that it presents no automatic limitation of the strength of vapour in use, and provides no means by which the administrator can ascertain what is the actual strength he is employing.

As regards mixtures, the same objections exist, with the additional one that, owing to the difference in the boiling-points of the ingredients, it is impossible to obtain anything like an accurate percentage value for the chloroform which is being given off.

Passing on to the mechanical inhalers we may note that Bert's method of mixing chloroform vapour in air in large receivers, although fairly exact, is unsuitable for routine employment, and, further, does not allow of the necessary variation in the percentage. It has passed out of use.

We have at the present time a considerable accumulation of clinical

¹ The Report of the Committee, published with original papers by the British Medical Association, 1911, price 1s., furnishes abundant evidence in favour of the maximum limit of safety being placed at 2 per cent.

experience bearing upon the employment of dosimetric inhalers. More or less exact regulating inhalers which are fairly compact have come into use, and many persons have been anæsthetized by their means: Snow's, Clover's, and the Roth Dräger apparatus permitted a higher percentage than 2 per cent., and the means by which the percentage is lessened is inexact. With all of these deaths occurred during their use, owing to the 2 per cent. strength being exceeded. The regulators of Dubois, of Waller, and of Alcock are exact, and are constructed upon the plenum system, which renders breathing easy. These have given excellent results, although from their bulk they are more adapted for hospital than private use. Among 'draw over' inhalers the Vernon-Harcourt has received the widest publicity and has been most employed. Dr. Levy's inhaler is on similar lines, but permits a maximum of 3·5 per cent.

My own experience is chiefly with the Vernon-Harcourt Regulator, and although I have used most of the other forms, I propose to speak mainly of this regulating inhaler. Its maximum is 2 per cent.; however, by using an increase tube, an undesirable addition, it is possible to produce 2·5 per cent., or, indeed, any percentage if the inhaler is specially graded for it. My experience, now extending over nearly ten years, has convinced me that, provided an accurate technique is practised, 2 per cent.; need not be exceeded. Very muscular and very obese subjects take a longer time to go under, and when time is an important matter, as in hospital work, a rapid induction with nitrous oxide and ether preceded by an injection of gr. $\frac{1}{100}$ of atropine is often serviceable. I employ oxygen with the chloroform not because the patient has any difficulty in breathing, or becomes cyanosed when this inhaler is in use, but because I am convinced that oxygen by maintaining the vigour of the tissues is a safeguard under any form of anæsthesia. Oxygen also lessens shock and counteracts the tendency of the tissues to weep when large areas are incised or denuded of their covering. The failure to produce complete anæsthesia with a 2 per cent. vapour is usually if not always the result of badly-fitting masks or unskilled handling, so that although the machine registers 2 per cent. the actual percentage inhaled falls short of it. The use of a flanged mask lessens the danger of leakage. In some surgical operations deeper narcosis than the third degree—i. e. anæsthesia—is called for by the surgeon. When this is so the use of a dosimetric inhaler is more than ever desirable, since the danger zone is entered, and the anæsthetist requires a scientific instrument which enables him to control the higher percentage, increasing it at critical points in the operation and lowering it when these are passed. At all events, he knows exactly what percentage he is employing, and retains absolute control of the anæsthetic.

It is alleged that dosimetric inhalers introduce an asphyxial element, and, further, that they are inapplicable for many types of operation. These statements, however, arise from misapprehension, or from lack of experience of the method. Cyanosis does not ever occur as a result of using an inhaler; when it arises it is due to preventable complications,

such as the faulty position of the patient, allowing fluid or other foreign material to occlude the airways or permitting the jaw to drop. Any of these possibilities may arise whatever method of giving chloroform is in use, and are so well known that any expert anæsthetist will foresee and guard against them. The dosimetric inhalers in common use are supplied with nasal and mouth tubes, and the definite percentage vapour can be either inspired by nasal tubes from a Vernon-Harcourt inhaler, for example by Crile's method for operations about the buccal cavity, or can be propelled by a hand-pressure ball or foot-bellows similar to the plan adopted when a Junker's bottle is in use.

I may add that since adopting the dosimetric method I have seen fewer complications, and have been enabled to safeguard patients from chloroform collapse. The appearance of a patient after even a prolonged inhalation of chloroform, when a dosimetric method has been employed, is in striking contrast to what is seen when unstinted quantities of the drug have been inhaled. The one is of almost normal colour and suffers few after-effects, while the other is pale, drawn, vomits, and is collapsed to a greater or less degree. It is the difference between chloroform acting as an anæsthetic and chloroform acting as a tissue poison,—between anæsthesia and toxæmia.

The technique is too well known to need detailed description, but for those who have not employed it I may say that it is fully described by me in the *Report of the British Medical Association* referred to above. The controlling principle is that a gradual increase of percentage vapour of chloroform in air is presented to the patient, and that as soon as anæsthesia is established the percentage is lowered to the requisite strength, so that the intake equalizes the output from the lungs. It need hardly be said that a dosimetric inhaler is a scientific instrument, and so requires scientific handling. A further point in favour of such apparatus is that, whatever changes may occur in the patient's breathing, the strength of vapour which he inhales can never exceed what we believe to be a safe strength, that is 2 per cent. ; even struggling need not call for restriction of the supply, although it may indicate the wisdom of lowering the strength of it.

In conclusion, then, I may say that I believe, both from experimental and clinical evidence, dosimetric methods of giving chloroform are the only safe means of exhibiting that drug, and by their use its dangers are abolished or so far lessened as to be negligible.

SUB-SECTION VII (b)

ANÆSTHESIA

DISCUSSION No. 3

A COMPARISON OF THE IMMEDIATE AND AFTER EFFECTS OF SPINAL AND LOCAL ANALGESIA, WITH THOSE OF INHALATIONAL ANÆSTHESIA, IN RESPECT TO SHOCK AND PSYCHIC SHOCK

REPORT BY YANDELL HENDERSON, PH.D., PROFESSOR OF PHYSIOLOGY IN THE YALE MEDICAL SCHOOL, NEW HAVEN, CONN., U.S.A.

ALL theories of shock and of the relations of anæsthesia to shock recognize that anæsthesia consists fundamentally in the blocking of afferent nerve-paths. This is the case both in general anæsthesia and in local analgesia. It is equally true no matter whether the anæsthesia is induced by inhalational, intra-spinal, intra-venous, subcutaneous, or any other method. The various modes of anæsthesia differ mainly in respect to the extent and location of the paths blocked. In order to compare one mode with another in the prevention of shock, we must first form a clear conception of what may be called the strategy of anæsthesia. As the nervous system is the battle-field with highways and cross-lanes over which attack may be made and resisted, we must determine the points of vantage to be held in order that the enemy, whether conscious pain, or subconscious afferent irritation, may be prevented from either assaulting or flanking our defences.

Pain is a phenomenon of overwhelming impressiveness not only to the sufferer but also to the sympathetic observer. As a result of this fact both laity and surgeons have been misled into thinking of anæsthesia as consisting mainly in the prevention of pain. In reality anæsthesia is far more. It is the means by which we obviate to a greater or less degree the development of shock. Surgery, before the discovery of anæsthesia, and surgery since, differ not only in the fact that the operating-room has ceased to be a chamber of torture, but rather in this that the patient is no longer liable to die of shock on the table or soon after leaving it. In the pre-anæsthetic period a major operation was generally followed by hours or days of profound depression (even apart from the then inevitable sepsis). The modern patient, on the contrary, usually exhibits merely a relatively slight and temporary depression of vitality. If shock followed operations under anæsthesia to the same degree that it would if they were performed without anæsthesia; in other words, if anæsthesia did not

prevent shock as well as pain, the greater part of modern surgery would be impossible. The prime objects of progress in anæsthesia are first to reduce deaths during and immediately after operation to the vanishing point ; to render major surgery 'as safe as crossing the street'. And second to make it possible to perform any and all operations, even the most severe, without appreciably reducing the vitality of the patient.

Pain may be defined as the consciousness of abnormally intense afferent irritations. In the production of shock by pain consciousness is, however, only a secondary element. The primary element consists in the effects induced by the excitement of the nerve centres below the level of consciousness, especially those in the medulla oblongata controlling the vegetative functions of the body. It is highly probable that shock could be induced by irritating afferent nerves in an animal from which the cerebrum had been removed. Such an animal, having no real consciousness, could scarcely be said to suffer pain ; and yet it would certainly exhibit practically all the signs and reactions of suffering. The central area of the nervous system is the medulla oblongata, the basal ganglia, and the nerve cells (or synapses) of corresponding rank in the spinal cord. The cerebrum is peripheral to these structures. It is, so to speak, on the opposite side of them from all the rest of the body. It can express itself only through them. All the impressions that it receives informing it of the state of the body and the outside world must come to it through relays in the central grey matter of the nervous system. We know really very little regarding the physiology and psychology of pain. James's theory of the emotions has great suggestiveness in this connexion. According to it the consciousness of suffering is merely the recognition by the mind that the body is acting as if it were abnormally irritated.

Although the cerebral centres are not themselves the main location of shock development, they are none the less a broad avenue through which the medullary centres are open to attack. Thus purely mental suffering, disappointment, or sorrow, or fear may act through the cerebrum (their supposed seat) upon the medullary centres to induce shock in much the same way, and at times with almost as great force, as do the over-excited receptors of a crushed foot or scalded hand. The timid excitable patient is peculiarly prone to shock. On the other hand, the wounded soldier, sustained by professional pride and patriotic enthusiasm, opposes the resisting power of the will to inhibit the medullary centres from giving way before the bombardment of irritations reaching them from the seat of injury. Hence the importance of taking care to avoid fear, and to develop hopefulness and courage in the mind of the patient. Moreover, the mind, as a locus of irritation, is in one respect more important than any other. By means of the imagination it may continue to reproduce suffering long after pain has ceased to be actually felt ; and this rehearsal carries with it in some degree the same evil influence upon the vegetative processes of the body as did the original state of mind.

Thus we are led to formulate these principles : To prevent psychic shock and the physical depression which it involves we must avoid exciting fear ; we must leave no memory of pain. To escape the development of physical shock we must not merely avoid pain, but even apart from the consciousness of suffering we must prevent the transmission of excessive afferent irritations to the centres controlling the vegetative processes of the body. And especially we must avoid certain procedures which are unfortunately still common in the administration of general anæsthesia, and which, as I shall later point out, are potent elements in the production of shock.

The application of these principles to local and intra-spinal analgesia is quite simple. These procedures are adequate, so far as the prevention of shock is concerned, whenever they suffice to prevent all pain, providing that the patient is of such mental poise, or is so treated, or so drugged, that fear and anxiety are also eliminated. A surgeon accustomed to the conditions of general anæsthesia is prone to forget that a patient under spinal analgesia is fully conscious, and that the state of mind is an element in operative success worthy of consideration. Thus in one case, that of an excitable woman, the patient emitted piercing shrieks at frequent intervals, while the surgeon, confident that she really felt nothing, as was in fact true, proceeded calmly with his work. Such a subject should at least have had a good dose of morphine, and would perhaps have been the better for the addition of ether. On the other hand, in another case, that of a phlegmatic man, all that was needed to quiet the mind was the morning newspaper. Under this soporific influence he fell asleep, and only waked when the operation was over and he was being removed to his bed. It is to be especially remembered that absolute quiet should be maintained, and any word or act that can cause anxiety be carefully avoided.

Before proceeding to the much larger topic of the relations of afferent irritation and of general anæsthesia to shock involving the entire organism, it is essential to say a few words on the question ' What is shock ? ' As I shall have occasion to present a more complete discussion of this topic before the Section of Pathology, I need touch here upon only a few salient points.

The term shock is used loosely (how loosely few seem to realize) to indicate conditions of greatly depressed vitality. It is also applied to a rapid death preceded by an injury which in itself would be insufficient, so far as can be seen, to account for the fatal termination. There are probably many forms of shock. They present similar appearances, just as two different sorts of fever may have the same temperature, but in their ætiology they may differ fundamentally. Most of the clinical forms, with the exception of that due to hæmorrhage, and possibly also that due to burns, appear to be the result of abnormally intense excitement of the centres in the medulla oblongata. This is the case in the shock wholly due to pain, and in that resulting from prolonged ether

excitement. I wish to emphasize the point, however, that neither in these forms, nor in any other so far as I can see, except such as are purely experimental, do the medullary centres themselves give way. Recent progress is opposed to the idea that clinical shock consists in a direct inhibition of these centres. Shock is not a prolonged syncope. We must abandon the view which has prevailed now for half a century that surgical shock consists in fatigue of the vaso-motor centre. Porter has shown that this centre is capable of withstanding almost unlimited irritation without becoming fatigued. Moreover, depression of respiration, the loss of tonus and peristalsis in the intestine, and failure of other functions also are quite as important in some forms of shock as are circulatory changes. In none of these functions, however, is the seat of the trouble in the medullary centres, although all are the results of medullary excitement. In some cases it appears to be a matter of excessive adrenalin secretion reflexly induced. This may be to some extent the case in the results of intense fear, for Cannon found the adrenalin content of the blood greatly increased in cats exposed to a barking dog. This may be the case also in the sudden heart failure under light chloroform anæsthesia, as the interesting experiments of Levy performed in Cushny's laboratory suggest. In other cases the excessive respiration induced alike by intense sorrow, by irritation of afferent nerves, and by the stage of excitement under anæsthetics results in a reduction of the body's content of CO_2 and induces a condition of acapnia. As this is a topic on which I have myself done a considerable amount of work, I trust that I may be excused for discussing it in some detail. Up to this point we have considered the part that anæsthesia plays in preventing shock. I wish now to point out how potent unskilful anæsthesia may be to induce shock.

Progress in physiology during the past few years, and especially the work of Haldane and his collaborators, has established beyond all question the fact that the normal stimulus to the respiratory centre is the CO_2 in the blood. It is this influence, and not an adjustment to oxygen needs, which keeps us breathing. Any one can do the crucial experiment demonstrating this at any time. Force yourself to breathe much more deeply and a little more rapidly than usual for a few seconds or minutes; and when you cease forcing your respiration you will for a time stop breathing altogether, or else breathe only occasionally or in a very shallow manner. The explanation is quite simple. You have diminished the store of CO_2 in your blood and tissues, and especially in the respiratory centre; and the centre accordingly remains quiescent until the CO_2 reaccumulates up to the stimulating amount. If you have persisted in the forced breathing for several minutes, the subsequent apnoea may last until the oxygen lack becomes acute, and you turn blue in the face. The condition of diminished CO_2 is called acapnia from the Greek word *kapnos*, or smoke. Literally acapnia means smokelessness.

In normal life the sensitiveness of the respiratory centre varies extremely little; and the automatic rate and depth of breathing maintain

the CO_2 content of the blood extraordinarily constant. Under various forms and degrees of anæsthesia, on the contrary, wide variations occur—variations from 50 per cent. below to 50 per cent. above normal. By analyses of the gases of the blood of forty-five dogs I have shown that anæsthetics alter the sensitiveness of the respiratory centre to an extraordinary degree. During light ether anæsthesia, in the so-called stage of excitement, and especially when the administration is intermittent and the subject comes part way out of anæsthesia, the sensitiveness of the centre is greatly increased. The subject therefore breathes excessively. A condition of acapnia is thus developed far more intense than a man can induce in himself by voluntarily forced breathing. In the same way a subject who is scared and excited before anæsthesia breathes excessively. Acute pain likewise produces hyperpnœa, and results in acapnia. On the other hand, full anæsthesia restores the respiratory centre to a nearly normal sensitiveness; and deep anæsthesia renders the centre much less sensitive than normal.

It is easy to see that any subject, human or animal, will stop breathing when the degree of anæsthesia is such that the centre is insensitive to the amount of CO_2 present at that moment in the blood. If the subject has been rendered acutely acapnic by the excessive respiration of intense pain, hysterical emotion, or by ether excitement, he is liable to stop breathing if he is later brought into even a very moderate depth of anæsthesia. In a series of experiments in which I have intentionally reproduced the conditions of unskilful anæsthesia by maintaining ether excitement for fifteen or twenty minutes, the subjects (dogs) came into such a condition of acapnia that respiration sometimes failed, and failed fatally, when the animal was so lightly anæsthetized as to wink its eyes. In the laboratory, just as in the operating room, the heart in such cases continues for a time to beat with undiminished force. If artificial respiration is administered soon enough, spontaneous breathing can usually be restored and death prevented.

In another series of intentionally unskilful anæsthesias on dogs a considerable degree of acapnia, and probably also an excessive adrenalin secretion, were induced either by allowing the subject to fight during ether excitement or by the hyperpnœa of pain. A little chloroform was then administered. In such cases it frequently happened that the heart suddenly failed, either simultaneously with respiration or even before the breathing afforded any sign of impending danger. The subjects were wholly irrecoverable by any procedure short of massage of the heart.

The results of these experiments may be summarized thus: Dogs which have not been excited at any stage usually take chloroform well. If too much chloroform is given, respiration usually stops some time before the heart. If, on the contrary, the subject has been kept for any great while in a state of ether excitement, the hypersusceptibility thus produced renders even the strongest animals liable to sudden primary cardiac failure under an otherwise moderate dosage of chloroform.

Physiologists were for a long time inclined to deny the occurrence of primary heart failure under chloroform. These experiments show not only that primary heart failure is a reality, but also that it is quite easily induced. It is only necessary that the experimental conditions should be an accurate reproduction of those under which such deaths occur clinically. What these conditions are may be illustrated by the following typical case: Male, 55 years old, moderate user of alcohol; vigorous normal heart and sound lungs. Operation for hydrocele. Ether was administered, but difficulty was experienced in bringing patient under. After an unusual amount had been given without the desired result, chloroform was substituted with apparently satisfactory results. The operation was scarcely begun, however, when the patient was observed to be intensely cyanosed. In a moment he was pulseless, and soon after respiration ceased. This particular case was recovered, but only by the desperate remedy of opening the abdomen and massaging the heart through the diaphragm.

Here was a case of the type which is usually referred to as 'hypersusceptibility to chloroform'. In my judgement such a conception is wide of the mark. That man had no special susceptibility to chloroform up to the time when the first whiff of ether was administered. His hypersusceptibility was developed entirely by the prolonged period of ether excitement to which he had been subjected. His heart was thus rendered liable to sudden failure under an amount of chloroform which would otherwise have been borne with impunity.

Because of the fact that ether is ordinarily very slightly, if at all, toxic for the heart, the sudden deaths which sometimes occur under ether have been regarded as peculiarly enigmatic. The failure to recognize the underlying cause of such fatalities has been due mainly to the fact that dogs have hitherto been the principal experimental animals, and dogs rarely exhibit the phenomenon. Cats, on the other hand, and many human subjects after being subjected to prolonged excitement, are liable to die of primary circulatory failure under ether. They are hypersusceptible to ether in much the same way that over-excited dogs and persons are hypersusceptible to chloroform.

The observations upon which these statements are based were made on cats under anæsthetization by students in a laboratory course too large for close supervision by the instructor. Fatalities at one time became so frequent that my attention was fixed upon the sequence of events leading up to them. It soon became evident that the problem involved not only the physiology of the cat, but also the psychology of the anæsthetist. Often the student anæsthetist was one who for awhile had done very well. His first three or four cases had gone through the operation and experiment without the least trouble. He became a little careless, lost an animal, and was rebuked. With the next case his confidence was weakened. He was constantly afraid the subject was going to die. He was prone to take the cat out of the little tin box, in which anæsthesia

was begun, before it was fully under. Thereafter he gave the ether with such caution that the animal sometimes came out sufficiently to struggle and cry. Occasionally it had to be held while being brought under again. Fifteen or twenty minutes later, at a time when everything appeared to be going smoothly, the cat's heart suddenly stopped beating. The anæsthetist was quite sure that it was no fault of his own, but that he must be extra careful next time. Then, if he happened to be a high-strung and nervous man, he was almost certain to give too little ether, and thus to kill in four out of his next five feline anæsthesias. It is noteworthy that it was especially the wild cats, those which had been badly scared and which struggled and fought against anæsthesia, which were peculiarly liable to die thus suddenly.

Comparison of such laboratory observations with clinical reports, seems to show that in a large percentage of the patients succumbing to primary cardiac failure under ether the fatality is similarly attributable to an acute susceptibility developed by unskilful anæsthesia. Often the trouble arises merely from a loss of confidence on the part of the anæsthetist. In a certain hospital, at one time, even the best quality of ether seemed to have lost a large part of its potency and to have developed an exciting quality with bad after effects. It is probable that in reality the trouble was psychological rather than chemical, and that the anæsthetist simply needed sleep and rest, or better, a week in the country.

Fatalities of the class here discussed seldom occur after profound and prolonged anæsthesia. They are especially the sequel of light anæsthesia. Usually the accounts of such cases state expressly that the administration of ether was interrupted once or twice, or several times, thus allowing the subject to come nearly out of anæsthesia. It is most unfortunate that many even of our best text-books of pharmacology recommend the practice of occasionally interrupting the administration of ether. This is a procedure which, above all others, should be shunned. Present methods of operating upon the tonsils and adenoids almost of necessity involve intermittent administration of the anæsthetic. Accordingly deaths of the sort we are considering appear to be more frequent in such operations than in nearly any other. What happens may be illustrated by the following case, merely a tonsillar operation. Cocaine had proved ineffective in wholly overcoming the pain. The subject, an hysterical woman, was further excited by the sight of blood. It was decided to give a little ether. It was given. The woman promptly died; and all efforts at revival failed. Neither the patient and her family nor the surgeon had, prior to the operation, the slightest suspicion of any cardiac weakness or disorder.

The reports of such cases sometimes mention that the patient was almost out of anæsthesia and even winked his eyes a few seconds before the circulation suddenly failed. He may have drawn deep gasping breaths some time after the heart had completely stopped beating. When the operation is one for adenoids the writer of the report generally assumes

that status lymphaticus was the cause of death, although there may have been no autopsy. Even in those cases in which an autopsy is performed the pathologist's report sometimes indicates that if he had not been told what to find he would scarcely have found it. As soon as the deleterious methods of anæsthesia above described are generally understood and avoided the number of cases of so-called status lymphaticus will, I believe, show a sudden and marked decrease.

We need not here attempt to decide how far the fatalities in the cases and experiments above quoted were due to acapnia, and how far to excessive adrenalin secretion or other over-stimulated function. Fortunately human beings appear to be much more resistant to such disturbances than are most laboratory animals. The practical points to be emphasized are that both fear and anæsthesia excitement are potent factors in lowering vitality. They render the patient more liable to die under operation, and more certain to suffer from shock if he survives. To avoid these effects anæsthesia should always be induced as quickly as possible, and throughout its entire duration it should be as nearly uniform as possible. To attain these objects a liberal dose of morphine should, in the great majority of cases, be administered half an hour or more beforehand. If ether is to be the anæsthetic the patient should first be brought under nitrous oxide. If gas is not available it is safer to initiate anæsthesia with chloroform and then to change to ether rather than to subject the patient to the more prolonged period of excitement involved in the use of ether alone. Owing to the recent demonstrations of the toxicity of chloroform the day is soon coming when its use as the principal anæsthetic for a major operation will be recognized as unjustifiable. Nevertheless it will still have an important use as a preliminary to ether when gas is not available. The American statistics recently published by Gwathmey show that this is a safer method than etherization alone. My observations upon inexperienced student anæsthetists show that, although chloroform is peculiarly toxic for cats, it is in the long run safer for them to initiate anæsthesia with chloroform than with ether. On the other hand, chloroform should never, under any conditions, be administered after ether.

I wish to call particular attention to the subject of the revival of the practice of re-breathing in connexion with nitrous oxide oxygen anæsthesia by Gatch. In this method of administration the gas-oxygen mixture is placed in a rubber bag attached to a close-fitting face mask, and the patient continues to breathe and to re-breathe the same gas over and over again, oxygen being added as needed, until the accumulation of carbon dioxide begins to exert a markedly stimulating effect upon respiration. The bag is then emptied and refilled with a fresh mixture, and the process repeated. The demonstration by Gatch that this method has decidedly beneficial effects has been confirmed by a number of other competent observers and affords a clinical confirmation of the validity of the acapnia theory in relation to anæsthetic fatalities. As the result of Gatch's work

nitrous oxide oxygen, reinforced when necessary with a very small amount of ether, and administered by re-breathing methods, is being extensively adopted in America as the anæsthesia of choice for major operations involving a considerable amount of shock, or upon already shocked subjects.

Finally, it may be pointed out that the oxygen to be used in the operating-room should contain 5 to 10 per cent. of carbon dioxide. Theory teaches, and my own experiments have amply confirmed, that such a mixture is far more effective in restoring spontaneous breathing when respiration has failed under anæsthesia than is oxygen alone.

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